INSTRUCTION MANUAL

FOR THE

UHF Q METER

TYPE 280-A

BOONTON RADIO CORPORATION

BOONTON, NEW JERSEY

U.S.A.

1M/5-61/CP

Printed in U.S.A.

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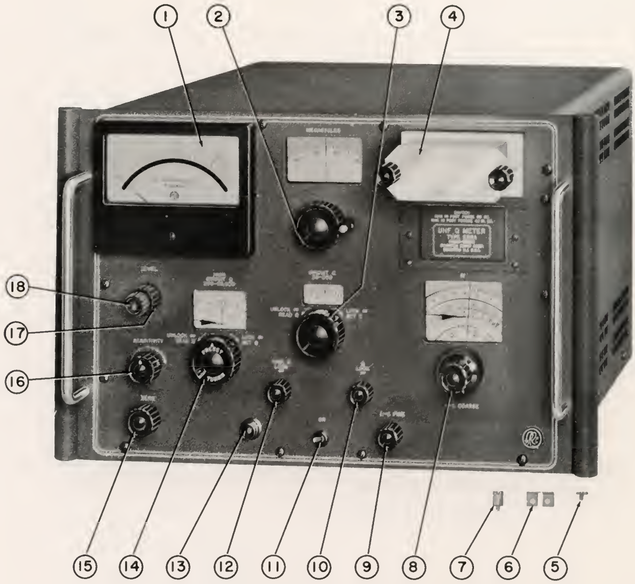


Figure 1. Type 280-A — Front Panel Controls

1. Panel Meter
2. Frequency Control
3. CIRCUIT Q Control
4. RF Shield
5. Terminal Screw
6. Terminal Clamp
7. Terminal Post
8. L-C COARSE Control
9. L-C FINE Control
10. Q LOCK
11. Power Switch
12. HIGH Q LOCK
13. Pilot Lamp
14. HIGH CIRCUIT Q Control
15. ZERO Control
16. SENSITIVITY Switch
17. Coarse LEVEL Control
18. Fine LEVEL Control

SECTION I

DESCRIPTION

GENERAL

The UHF Q Meter Type 280-A (Figure 1) measures the Q, capacitance, and inductance of components directly over a frequency range of 210 to 610 megacycles. Q is calibrated directly on the front panel dials from 20 to 25,000. The instrument will measure circuit Q from approximately 10 to 2,000 using the internal Q capacitor, and from 10 to 25,000 using an external resonator. Values of inductance from 2.5 to 146 millimicrohenries can be measured and read out directly on a front panel dial. The resonating capacitor range is 4 to 25 picofarads (micromicrofarads).

PANEL LAYOUT AND CONTROLS

A front view of the instrument, showing all of the operating controls, the resonance indicating meter, and the shielded measuring circuit terminal posts, appears in Figure 1. The resonance indicating meter is located in the upper left-hand corner of the instrument and the measuring circuit terminal posts are located under the shield enclosure in the upper right-hand corner of the instrument. All of the controls necessary for the operation of the instrument are arranged on the front panel in convenient functional order. The control functions are described in the following paragraphs.

Power Switch

The Power Switch applies line voltage to the power supply when set to the ON position.

Fuse

A 1.5-ampere slow blowing MDL type fuse, located at the rear of the instrument (Figure 2), is connected in the ac line.

Pilot Lamp

A lamp, connected across a 6.3 vac filament winding of the power transformer, lights when the power is on.

Panel Meter

Four points are marked on the panel meter scale: 0, Q, $\frac{Q}{2}$, and a full-scale point. The 0 point is used in conjunction with the ZERO control to adjust the meter to electrical zero. The full-scale point is used with the LEVEL control to adjust the peak of the detected resonance curve for full-scale deflection on the meter. The Q point is used in conjunction with the CIRCUIT Q or HIGH CIRCUIT Q controls, depending upon the value of Q being measured, to indicate the 3-db or bandwidth measuring points on both the left (low-frequency and right-hand (higher frequency) sides of the detected resonance curve. The $\frac{Q}{2}$ point on the meter scale is similarly used with the CIRCUIT Q control to indicate the bandwidth measuring points on the resonance curve when the Q being measured is between 10 and 20. In the latter case, the CIRCUIT Q dial reading is divided by 2 to obtain the correct Q measurement.

ZERO Control

This control is used to set the panel meter pointer to the 0 point on the meter scale before the measurement procedure is started.

LEVEL Control

The LEVEL control is part of a pulley and cable drive system which drives the piston attenuator and adjusts the injection voltage level into the Q capacitor. The outer concentric knob provides for coarse adjustment of the voltage level and the inner concentric knob provides for fine adjustment of the voltage level. In the measurement procedure, the LEVEL control is used to set the peak of the detected resonance curve at the full-scale point on the panel meter. The coarse control has three complete operational turns; additional turning will only result in slippage of the drive mechanism. When measuring medium and high Q components, start the measurement procedure with the coarse control in the center of the operating range and the fine control in the full clockwise position. For low Q measurements, the initial setting of both controls should be the extreme clockwise position for maximum injection voltage level. Both controls are operative for measurements at the Q capacitor terminals. Only the fine control is operative for external resonator measurements. See SENSITIVITY Switch for correct sensitivity settings for low, medium, and high Q measurements.

SENSITIVITY Switch

This switch has five positions which when the fine LEVEL control is set full clockwise, divide the dc sensitivity range of the panel meter from approximately 2000 μv full-scale in the extreme counterclockwise position to 20 μv in the extreme clockwise position. Since the detector is square law, this represents an rf injection voltage range of from 250 mv to 25 mv. The SENSITIVITY switch should be normally set to provide minimum sensitivity (full counterclockwise position). Increased sensitivity will normally be required only when measuring low-level devices, or when it is not possible to obtain a full-scale indication on the front panel meter.

Frequency Control

The frequency control selects the frequency at which the measurement is to be made. Both the frequency control and the frequency dial are mounted on a shaft which is geared to the oscillator tuning shaft. The operating frequency is indicated at the fiducial line in the frequency dial window directly above the frequency control. The dial is directly calibrated in megacycles from 210 to 610.

CIRCUIT Q Control

The CIRCUIT Q control drives the CIRCUIT Q dial which reads out Q directly from 20 to 200. This control is geared to the oscillator tuning shaft, and translates the angular rotation of the shaft into percentage bandwidth of the resonance curve, this in turn being calibrated in Q on the dial. Q is read at the fiducial point in the window directly above the CIRCUIT Q control. The ∞ mark on the dial indicates the zero bandwidth point or the point at which the circuit is lossless or Q is infinite.

Q LOCK

The Q LOCK control operates a mechanism which prevents the CIRCUIT Q dial from turning when the CIRCUIT Q knob is rotated. This permits locking the CIRCUIT Q dial at the ∞ point while the oscillator is adjusted to the center frequency of the resonance curve, the level is set to full scale, and the frequency is set at the 3-db point below the resonance peak (Q mark on the meter).

HIGH CIRCUIT Q Control

The HIGH CIRCUIT Q control is part of a vernier Q measuring system which operates independently of the CIRCUIT Q (low Q) measuring system. Rotational motion of this control is converted to translational motion through a lever arm system driven by a micrometer. This lever arm system in turn rotates the oscillator through minute angular increments by means of special leaf springs on the oscillator stator mount. These minute increments of oscillator rotation are calibrated in Q from 200 to 25,000 on a two-turn spiral dial in a window directly above the HIGH CIRCUIT Q control. The ∞ mark on the dial is used as a starting point for all Q measurements. An arrow-shaped indicator denotes the scale to be read at the fiducial.

HIGH Q LOCK

The HIGH Q LOCK control operates a locking mechanism which prevents the HIGH CIRCUIT Q dial from turning when the HIGH CIRCUIT Q control is rotated. This permits locking the dial at the ∞ point while the oscillator is adjusted to the center frequency of the resonance curve, peaked, and then set to the 3-db point below the resonance peak.

L-C COARSE Control

The L-C COARSE control drives the Q capacitor through a gear and rack system. Concentric control knobs operate concentric dials which readout capacitance and inductance in a window directly above the L-C COARSE control. The outer (knurled) knob operates the inner dial which is composed of a two-turn spiral inductance scale calibrated in millimicrohenries, and a frequency scale calibrated in megacycles from 210 to 610. An arrow-shaped pointer indicates the inductance scale to be read.

The inner knob on the control operates the outer capacitance dial which is calibrated in picofarads (micromicrofarads) from 4 to 28. By means of a clutch built into the drive system, the concentric dials may be rotated together with the inner knob or the inner dial may be rotated independently by means of the outer (knurled) knob. The outer knob is depressed toward the front panel to disengage this clutch. This permits setting the inner frequency dial to the desired frequency while the capacitance dial is set to the SET FREQUENCY mark on the low end of the capacitance dial during inductance measurements.

The capacitor dial scale is automatically corrected for direct readout of equivalent UHF capacitance at the measuring circuit terminal posts. This correction is accomplished mechanically by means of a pully and cable drive system which is actuated by a cam operating from the oscillator rotor shaft. As the oscillator shaft is rotated, the fiducial is moved across the capacitor dial and an automatic correction is made in capacitance readout.

L-C FINE Control

This control is a vernier drive for fine tuning of the Q capacitor during capacitance and inductance measurements.

MEASURING CIRCUIT TERMINALS

The UHF Q Meter is designed and calibrated so that all of the front panel dials indicate plane-of-reference measurements made at the high stator of the Q capacitor on the front panel of the instrument. Components to be measured are connected to terminal screws threaded directly into blocks which are, in turn, connected directly to the high and low stators of the Q capacitor. There are three connection terminals on each stator block. These blocks lie in the same vertical plane as the front panel of the instrument.

In order to prevent damage to the Q capacitor during connection of components, the terminal screws have been undercut just below the binding heads so that they will break if too much torque is exerted during the tightening operation. For this reason, it is recommended that only the terminal screws furnished with the instrument be used.

The terminal screws are very small (#2) and have been silver plated in order to maintain a low-loss connection.

An rf shield, furnished with the instrument, shields the component under test from spurious rf signals and loss of energy by radiation. The shield is readily removed and installed by means of two quarter-turn fasteners.

RF OUTPUT CONNECTORS

There are five rf connectors mounted on a panel at the rear of the instrument (Figure 2). The extreme left-hand connector (J1) is lightly coupled to the output of the oscillator. Coupling is so light, that any loading at this point will not affect the stability or accuracy of the oscillator. A precision frequency counter may be connected to this connector to monitor the oscillator frequency. The upper coaxial jumper on the panel connects the output of the oscillator (J3) to the input of the piston attenuator (J2). The lower jumper connects the output of the diode in the Q capacitor assembly (J5) to the input of the high-gain dc chopper amplifier (J4). Access to these outputs at the rear of the instrument pro-

vides a means for performing measurements on external resonators.

The procedure for making external resonator measurements is given in Section III. A diagram showing the proper jumper connections is shown in figure 8.

Note: *When making external resonator measurements, ground must be connected from J3 to J4.*

SECTION II

SPECIFICATIONS

Radio Frequency Characteristics

RF RANGE: 210 to 610 Mc
RF ACCURACY: ±3%
RF CALIBRATION: Increments of approximately 1%
RF MONITOR OUTPUT: 10 mv minimum into 50 ohms (at frequency monitoring jack J1)

Q Measurement Characteristics

Q RANGE: Total Range — 10 to 25,000*
High Range — 200 to 25,000*
Low Range — 10 to 200

*approximately 10 to 2,000 employing internal resonating capacitor

Q ACCURACY: ±20% of indicated Q

Q CALIBRATION: High Q Scale — Increments of 1 to 5% up to 2,000
Low Q Scale — Increments of 3 to 5%

Inductance Measurement Characteristics

L RANGE: 2.5 to 146 mμh (Actual range depends upon measuring frequency.)

L ACCURACY: ±11 to 15% (Accuracy depends upon resonating capacitance.)

L CALIBRATION: Increments of approximately 5%

Resonating Capacitor Characteristics

CAPACITOR RANGE: 4 to 25 pf

CAPACITOR ACCURACY: ±(5% + 0.2 pf)

CAPACITOR CALIBRATION: 0.05 pf increments, 4 to 5 pf
0.1 pf increments, 5 to 15 pf
0.2 pf increments, 15 to 25 pf

Measurement Voltage Level

RF LEVELS: 25, 43, 79, 137, 250 mv nominal (across measuring terminals)

Accessories Furnished

Type 530A Terminal Shield
307510 Terminal Screws (18)
307584 Terminal Posts (6)
307649 Terminal Clamps (3)

Accessories Available

Type 580-A Probe Kit (For early models)
Type 580-B Probe Kit (For late models)

Complement of Electron Devices

11 — 1N1763 Diode
2 — 1N536 Diode
1 — 1N82 Diode
1 — 12AT7
3 — 12AX7
2 — 2N554 Transistor
2 — 31A-7H Diode
1 — 31G-7H Diode
1 — 31G-12L Diode
1 — 5651
1 — 5751
1 — 6080
1 — 6CL6
1 — DET-22 (Genalex)
1 — NE-2 Lamp
1 — Lamp, GE #47
4 — Lamp, GE #12 (2 pin)

Physical Characteristics

MOUNTING: Cabinet for bench use; by removal of end covers, suitable for 19-inch rack mounting

FINISH: Gray wrinkle, engraved panel (other finishes available on special order)

DIMENSIONS: Height — 12-7/32 inches
Width — 19 inches
Depth — 17 inches

WEIGHT: Net — 72 lbs.

Power Requirements

280-A: 105-125/210-250 volts, 60 cps, 140 watts
280-AP: 105-125/210-250 volts, 50 cps, 140 watts

Figure 2. Type 280-A — Rear View

SECTION III

OPERATING INSTRUCTIONS

GENERAL

This section describes the procedures to be used for making direct Q, capacitance, and inductance measurements on the UHF Q Meter. It is necessary to have an inductor connected across the measuring circuit terminals to complete the measuring circuit before any measurements can be made. The measuring circuit may then be tuned to resonance, by means of the L-C controls and the Q controls, with the oscillator set at a given operating frequency, or by presetting the Q capacitor to the desired value with the L-C controls, and then adjusting the oscillator frequency. Resonance will be indicated on the front panel meter in either case.

Indicated Q (which is the Q read directly on the CIRCUIT Q or HIGH CIRCUIT Q dials) is referred to in this discussion as *circuit* Q because it includes the losses of the total resonating circuit. The *effective* Q of the measurement will be greater than the *indicated* Q, but the difference in the two values is generally negligible. However, in certain cases, the Q readings may require correction. The procedure for computing these corrections is described in Section V.

INSTALLATION

Remove the UHF Q Meter from its shipping carton and place it in position on a test bench. If the instrument is to be installed in a rack, remove the end bells.

Power Source

The UHF Q Meter is available in two models: the Type 280-A which is wired at the factory for 115-volt, 60 cps operation, and the Type 280-AP which is wired at the factory for 230-volt, 50 cps operation. To convert from 115-volt operation to 230-volt operation, or vice versa, change the connections of the power transformer at terminal board "E" (Figure 24) as shown in Figure 3. At the same time, change the MDL fuse (F1) at the rear of the instrument (Figure 2). To convert from 60 cps operation to 50 cps operation, or vice versa, change the plug-in Twin-"T" filter (FL5 on Figure 23). Descriptions and part numbers of the fuses and filters are given in the Table of Replaceable Electrical Parts.

Preliminary Procedure

Before connecting the instrument to the power source, adjust the mechanical zero of the panel meter. Connect the instrument to the appropriate power source and set the power switch to ON. Routine measurements may be made a few minutes after the power is turned on. A warm-up time of at least one hour is recommended, however, before precision measurements are made.

OPERATING PRECAUTIONS

The UHF Q Meter operates on a somewhat different principle than conventional Q Meters, and therefore it is recommended that the user refer to Section IV, which describes the principle of operation of the Q measuring circuit, before attempting to operate the instrument. Familiarity with the sources of errors information in Section V will also aid the user, especially in obtaining and interpreting precision measurement data.

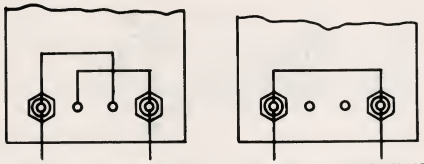


Figure 3. Connections for 115-volt and 230-volt operation

Before connecting the instrument to the power source, be sure that the power transformer is properly connected for the line voltage being used (Figure 3).

Only the terminal screws provided with the instrument should be used. These screws are silver plated to provide low resistance. Extreme care should be used when connecting components with the screws as undue pressure might possibly cause damage to the Q capacitor assembly. The screws are undercut so that the heads will break if undue torque is exerted when they are being tightened. This minimizes the possibility of damaging the Q capacitor.

PARALLEL MEASUREMENTS

There are two basic methods of connecting components to the measuring circuit of the UHF Q Meter. The nature and magnitude of the impedance to be measured usually dictates the method to be used.

Direct Measurements

Most coils can be measured by connecting them across the Q capacitor terminals as shown in Figure 4. The inductance and resistance ranges of the instrument are shown in figures 6 and 7. Resistance is computed by means of the formulae given in the Appendix.

The measuring circuit is resonated by adjusting either the capacitance or frequency, and indicated Q is read on the CIRCUIT Q or HIGH CIRCUIT Q dial. The effective inductance of the coil is read on the spiral scale of the L-C dial, and the resonating capacitance is read on the pf scale on the L-C dial. See Section V for Sources of Error.

When the inductance to be measured at a specified frequency is limited by the minimum capacitance of the Q capacitor, its value and Q may be determined by using the procedure for making External Resonator Measurements. A small variable capacitor

may be calibrated and used to advantage in this application.

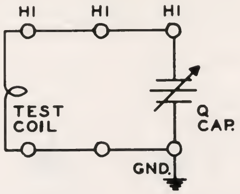


Figure 4. Connections for direct measurements

Indirect Measurements

High impedance components, such as high-value resistors, certain inductors, and small capacitors, are measured by connecting them in parallel with a stable work coil in the measuring circuit as shown in Figure 5. Before the unknown component is connected, the measuring circuit is resonated using a stable work coil to establish reference values of Q and C. With the work coil still connected across the Q capacitor terminals, the unknown component is also connected across the terminals and the capacitor is readjusted for resonance. The altered values of Q and C are then combined with the reference values in equations which will yield the parameters of the unknown component. The equations used are given in Tables I and II of the Appendix.

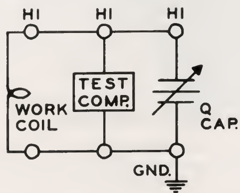


Figure 5. Connections for indirect measurements

SERIES MEASUREMENTS

At ultra-high frequencies, series measurements present a more difficult problem. First, shunt capacitance and series inductance of the series jig must be small relative to the impedance to be measured. Secondly, a low inductance and low resistance short-circuiting device must be employed.

In the Type 280-A, circuit component contact resistance and series resistance of the Q capacitor are basically the lower limiting factors in series measurements. The contact resistance usually becomes a function of the component shape and may require a special machined fixture for a given component. See Sources of Error, Section V.

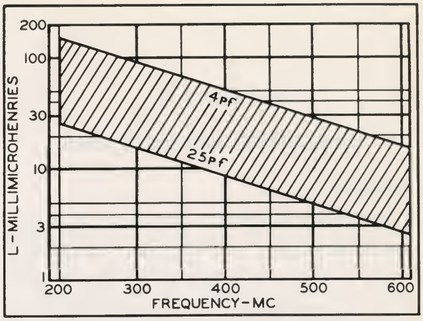


Figure 6. Inductance range of the UHF Q Meter (direct reading)

OPERATING PROCEDURES

Setup Procedure

Before the unknown component or reference inductor is connected in the measuring circuit, a preliminary setup of the front panel controls should be made as follows. See Figure 1 for location of the controls.

1. Set the frequency dial for the approximate operating frequency.
2. Turn the Q LOCK control full counterclockwise to unlock the CIRCUIT Q dial.
3. Rotate the CIRCUIT Q control until the ∞ mark on the CIRCUIT Q dial is aligned with the fiducial.
4. Turn the Q LOCK control full clockwise to lock the CIRCUIT Q dial.
5. Adjust the CIRCUIT Q control until the frequency dial indicates the exact operating frequency.

Note: *If greater frequency accuracy than the ±3% accuracy afforded by the oscillator in the UHF Q Meter is desired, the operating frequency may be set with a precision frequency counter connected to the FREQ monitor jack (J1) at the rear of the instrument (Figure 2).*

6. Turn the HIGH Q LOCK control full counterclockwise to unlock the HIGH CIRCUIT Q dial.
7. Rotate the HIGH CIRCUIT Q control until the ∞ mark on the dial is aligned with the fiducial.
8. Turn the HIGH Q LOCK full clockwise to lock the HIGH CIRCUIT Q dial.
9. Set the HIGH CIRCUIT Q control to the center of its operational travel (one and three-quarter turns from either stop with pointer up).
10. Rotate the L-C COARSE control inner knob full clockwise so that the SET FREQUENCY mark on the top (pf) scale of the L-C dial is under the fiducial.
11. Depress the outer (knurled) knob on the L-C COARSE control toward the front panel and adjust the inner L-C dial so that the frequency (lower) scale is set with the operating frequency under the fiducial.

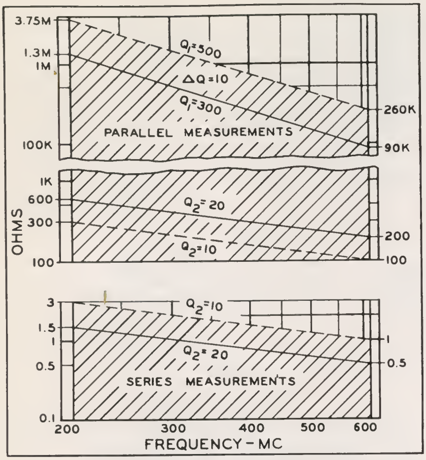


Figure 7. Approximate resistance Range of the UHF Q Meter

12. Rotate the coarse LEVEL control three turns counterclockwise and the fine LEVEL control full clockwise.
13. Set the SENSITIVITY switch to the full counterclockwise position for minimum sensitivity.
14. Zero the panel meter with the ZERO control.

Measurement Procedure

To measure the Q, inductance, or capacitance of an unknown component, preset the front panel controls in accordance with the instructions given in the Setup Procedure in the preceding paragraph, then follow the procedure given below. The procedure is the same whether the measurement is being made to determine reference data from work coils, or to determine the values of the unknown component.

1. Remove the rf shield (Figure 1) from the measuring circuit terminals. The shield is fastened to the Q capacitor assembly by means of two knob-operated quarter-turn fasteners which may be released by turning counterclockwise.
2. Connect the device to be measured across the measuring circuit terminals. See the paragraph entitled "Parallel Measurements" in this section.
3. Replace the rf shield over the measuring circuit terminals. Turn the knobs clockwise to lock the shield in place.
4. Rotate the coarse LEVEL control 3 turns clockwise and the fine LEVEL control full clockwise.
5. Rotate the L-C FINE control slowly until the panel meter pointer begins to move upscale.
6. Alternately adjust the LEVEL and L-C FINE controls until the panel meter pointer is peaked approximately at full scale.
7. With the HIGH CIRCUIT Q dial locked, alternately adjust the HIGH CIRCUIT Q and LEVEL controls for full-scale deflection on the panel meter.
8. Turn the CIRCUIT Q or HIGH CIRCUIT Q control clockwise until the panel meter pointer is below the Q mark and then counterclockwise until it is aligned with the Q mark ($\frac{Q}{2}$ mark for components with Q's between 10 and 20).

   Note: *If the Q of the component being measured is in the 10 to 200 range, use the CIRCUIT Q control. If the component has a Q in the 200 to 2,000 range, use the HIGH CIRCUIT Q control.*

9. Unlock the CIRCUIT Q or HIGH CIRCUIT Q dial.
10. Turn the CIRCUIT Q or HIGH CIRCUIT Q control counterclockwise so that the meter pointer moves upscale through the resonance peak and back to the Q (or $\frac{Q}{2}$) mark.
11. Read Q directly on the CIRCUIT Q or HIGH CIRCUIT Q dial. If the component being measured has a Q between 10 and 20, and the $\frac{Q}{2}$ mark was used in step 8, divide the CIRCUIT Q dial indication by two to obtain the correct Q value.
12. Read inductance directly at the fiducial on the L-C dial spiral inductance scale. The red arrow indicates the correct spiral scale to be read.
13. Read resonating capacitance directly at the fiducial on the L-C dial pf (top) scale.

EXTERNAL RESONATOR MEASUREMENTS

External cavities and circuits ("in-circuit" measurements) can be measured on the UHF Q Meter by disconnecting the internal Q capacitor at the rear of the instrument (Figure 2) and connecting the external resonator in its place as shown in Figure 8. Inductive and capacitive coupling probes, BRC Types 580-A or 580-B, are furnished as accessories to the UHF Q Meter for this application. Similar probes could be fabricated by the user for special purpose applications. The probes are shown being used to measure an rf amplifier circuit in Figure 9.

"In-Circuit" Measurements

The procedure for making "in-circuit" measurements is as follows:

1. Disconnect the jumper at the OSC (J3) connector (Figure 23).
2. Disconnect the jumper at the IND (J4) connector.
3. Connect the inductive probe (probe with coupling loop) to the OSC connector.
4. Connect the capacitive probe (diode probe) to the IND connector.

The probes should be interconnected and grounded.

Note: *Early production models of the Type 280-A are not equipped with a fine LEVEL control. For this reason, a 1 megohm dc poten-*

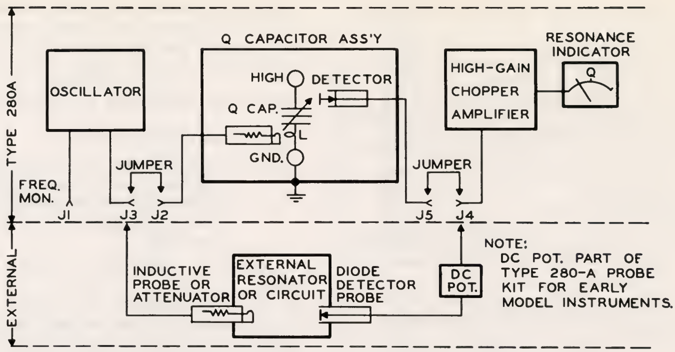


Figure 8. Connections for external resonator measurements

tiometer is furnished with the Type 580-A Probe Set to provide a means for adjusting the voltage injected into the external resonator.

5. Set the frequency control for the approximate desired frequency.
6. Turn the HIGH CIRCUIT Q dial to the ∞ mark and lock the dial.
7. Turn the HIGH CIRCUIT Q control 1¾ turns from either stop (pointer up).
8. Set the SENSITIVITY switch to the desired sensitivity range.
9. With the probes retracted in their tubular shields and away from the resonator to be tested, set the ZERO control for zero indication on the meter.
10. Place the test resonator on a small ground plane.

Note: *A shield may be used between the probes and the test resonator as shown in figure 9.*

11. Position the probes, fully extended, near the resonator.
12. Using the CIRCUIT Q control, sweep the frequency from minimum toward maximum, until a peak indication is observed on the meter.
13. Adjust the following so that the resonant peak is precisely at full scale on the meter:

a. The position of the probes, relative to the test resonator.

b. The position of the probes within their tubular shield.

c. The fine LEVEL control (external dc potentiometer on early models).

d. The HIGH CIRCUIT Q control.

14. Turn the CIRCUIT Q or HIGH CIRCUIT Q control (depending upon the Q being measured) clockwise until the meter pointer is below the "Q" mark and then counterclockwise until it is aligned with the "Q" mark. Unlock the CIRCUIT Q or HIGH CIRCUIT Q dial.
15. Turn the CIRCUIT Q or HIGH CIRCUIT Q control counterclockwise so that the meter pointer moves upscale, through the resonance peak, and back to the "Q" mark on the meter.
16. Read Q directly on the CIRCUIT Q or HIGH CIRCUIT Q dial.

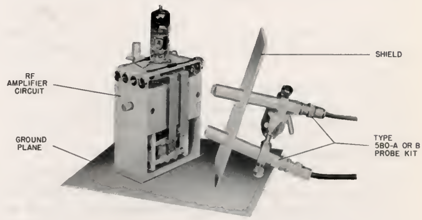


Figure 9. "In-circuit" Q Measurement

External Cavity Measurements

The procedure for measuring external cavities is as follows:

1. Disconnect the jumpers at connectors J3 and J4 (Figure 22).
2. Connect the cavity through an adjustable attenuator to connectors J3 and J4 as shown in Figure 8.
3. Set the frequency control for the approximate desired frequency.
4. Turn the HIGH CIRCUIT Q dial to the ∞ mark and lock the dial.
5. Turn the HIGH CIRCUIT Q control 1¾ turns from either stop (pointer up).
6. Set the SENSITIVITY switch to the desired sensitivity range.
7. With the attenuator control set for minimum injection, set ZERO control for zero indication on the meter.
8. Sweep the frequency from minimum to maximum with the CIRCUIT Q control until a peak indication is observed on the meter.
9. Adjust the attenuator control and HIGH CIRCUIT Q control until the peak is precisely at full scale.

10. Turn the CIRCUIT Q or HIGH CIRCUIT Q control (depending upon the Q being measured) clockwise until the meter pointer is below the "Q" mark and then counterclockwise until it is aligned with the "Q" mark. Unlock the CIRCUIT Q or HIGH CIRCUIT Q dial.
11. Turn the CIRCUIT Q or HIGH CIRCUIT Q control counterclockwise so that the meter pointer moves upscale, through the resonance peak, and back to the "Q" mark on the meter.
12. Read Q directly on the CIRCUIT Q or HIGH CIRCUIT Q dial.

SECTION IV

THEORY OF OPERATION

GENERAL

A simplified block diagram of the UHF Q Meter is shown in Figure 10. The instrument consists essentially of a variable butterfly oscillator, an inductive signal injector, a Q capacitor, a capacitive coupled silicon diode detector, a high-gain chopper amplifier, a resonance indicating meter, and a regulated power supply.

Tuning of the oscillator to the desired operating frequency is accomplished by means of a main frequency control and CIRCUIT Q control geared to the oscillator shaft, and a HIGH CIRCUIT Q control which rotates the oscillator stator. Output from the oscillator is inductively coupled to the Q capacitor measuring circuit by means of a piston attenuator.

The component to be measured is connected across the Q capacitor terminals and the measuring circuit is tuned to resonance with the L-C COARSE and L-C FINE controls which vary the capacitance of the Q capacitor. Output from the resonant Q measuring circuit is detected by means of a voltage probe connected to a high-gain amplifier and is indicated on a panel meter. This meter has only four calibration points which are used by the operator to set up the meter zero, and the peak and bandwidth voltage points of the resonance curve. Q, resonating capacitance, and inductance are then read out directly on the dials.

Q MEASURING TECHNIQUE

When dealing with Q at ultra high frequencies, it is easier to measure relative voltage levels, such as 3 db relative to the peak of a resonance curve, than it is to attempt to accurately meter absolute voltage levels. For this reason, the bandwidth measurement technique is used in the UHF Q Meter instead of the "resonance rise" technique which is used in lower

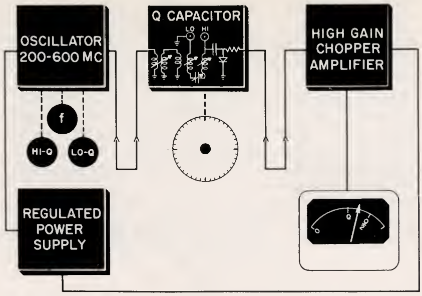


Figure 10. Simplified block diagram — Type 280-A

frequency Q Meters. The bandwidth measuring principle may be explained with the aid of the typical high Q resonance curve shown in Figure 11. V on the curve is the peak voltage at resonance; the .707 points are .707 times the peak voltage, or 3 db down from the peak level; f_0 is the center frequency, or frequency at which the measurement is being made, and Δ_f is the frequency excursion from the left-hand 3 db point, over the peak of the resonance curve, to the right-hand 3 db point. Q is derived from the simple bandwidth relationship: $Q \approx f_0/\Delta_f$ or the center frequency divided by the frequency bandwidth.

A conventional square-law silicon diode detector is employed to detect the 3 db bandwidth points. Since this detector is square law, 0.707 is squared and is indicated as 0.5 or one-half scale deflection on the resonance indicating meter.

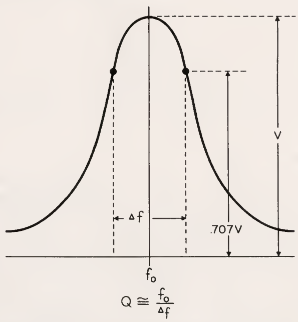


Figure 11. Typical high Q resonance curve

OSCILLATOR

The oscillator in the UHF Q Meter provides frequencies of 210 to 610 Mc. A simplified schematic diagram of the oscillator is shown in Figure 12. The oscillator is a conventional "butterfly" type, employing a rigid mechanical resonator, represented in Figure 12 as L1, C1, L2, and C2. The tube used in the circuit is a planar type, which has dc power handling

capabilities of 10 watts and a very high series resonant frequency characteristic. A constant current pentode is connected in the cathode return of the oscillator tube to hold the current change in the tube within reasonable limits, without a large dc series drop. A relatively high out (1 watt RF) insures sufficient isolation between the oscillator and the measuring circuit. The circuit has been carefully designed to eliminate spurious parasitic resonances and to provide for the dissipation of heat generated in the plate structure of the tube.

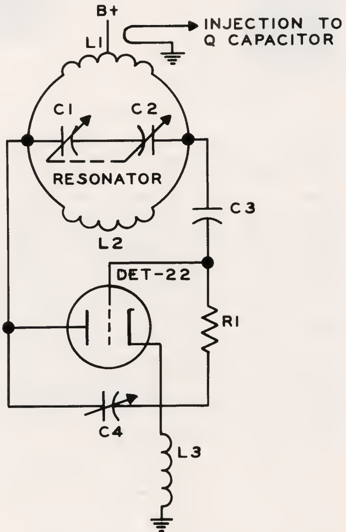


Figure 12. Simplified schematic — oscillator circuit

Oscillator Tuning

Tuning of the oscillator is performed manually by means of three front panel controls: the main frequency (MEGACYCLES) control, the CIRCUIT Q control, and the HIGH CIRCUIT Q control. The main frequency and CIRCUIT Q controls are geared to the oscillator shaft, the CIRCUIT Q control being a vernier for the main frequency control. The HIGH CIRCUIT Q control is a very fine tuning vernier used for high Q measurements, beginning at 200. This fine tuning vernier system rotates the entire oscillator butterfly stator by means of a micrometer drive mechanism, while the rotor is held fixed. The system is shown in Figure 13. The disk represents the stator support and the four lines marked "S" are spring-tempered beryllium copper. These springs are stiff in a radial direction but permit rotation when the micrometer spindle is advanced with the HIGH CIRCUIT Q control. The springs flex elastically in exact relationship to the micrometer motion, so there is no lost motion or backlash in the system.

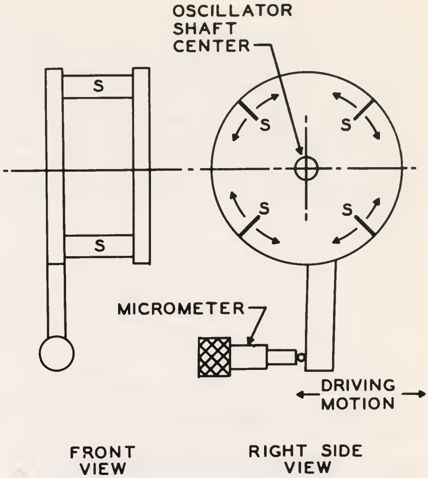


Figure 13. High Q vernier tuning system

Q CAPACITOR

The design of the Q capacitor in the UHF Q Meter is based on the effective capacitance concept, which provides that if a capacitor has a series inductance, the equivalent capacitance is given by the equation:

$$C_{eq} = C \times \frac{1}{1 - \omega^2 LC},$$

where ω equals the operating frequency times 2π. L varies inversely with C, so that L times C is a constant. This is equivalent to the series resonant frequency being constant and independent of capacitance. Therefore, at a given frequency, C_{eq} is equal to a constant times C, and the difference between C_{eq} and C is a constant percentage which is a function of frequency only.

The constant L times C design feature, together with the fact that the capacitor plates are shaped to provide a logarithmic capacitance variation, makes it possible to correct the capacitance dial by a constant percentage at any given operating frequency. This is accomplished by a simple motion of the indicating fiducial.

A cutaway view of the Q capacitor is shown in Figure 14. The plane-of-reference concept is used instead of the conventional binding posts, because with the high resonant frequencies anticipated, it is necessary to maintain very low inductance. The two capacitor stators present a common plane surface with an air gap separating them. Holes are tapped in the stator surfaces for connection of the components to be measured. The translator plates approach the stators from the bottom, allowing the effective path from the plane of reference to the capacitor to be advanced at the same time that the capacitance is increased. The plane of reference is slanted 20° to

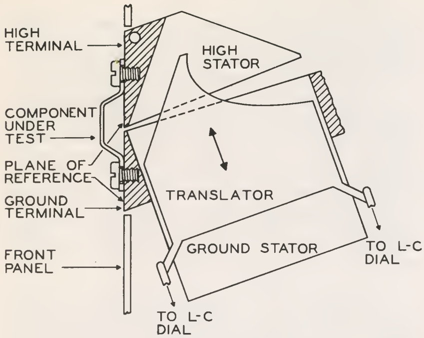


Figure 14. Cutaway view — Q capacitor

allow the translator plates to be moved as closely as possible to the plane of reference. The translator plates are curved to provide a logarithmic capacitance variation as they are moved into the capacitor stators.

The entire Q capacitor unit is well shielded to prevent spurious resonant structures. Linear ball bushings are used to support the translator plates so that there is minimum play in the plates as they are moved toward the plane of reference.

L-C Dial Correction

Since the Q capacitor is designed with constant L times C and the capacitor plates are shaped to provide logarithmic capacitance variation, the capacitance dial is correctable by a constant percentage at any given operating frequency. This percentage correction is equivalent to a given angular rotation of the readout hairline with respect to the capacitance scale. The hairline is rotated, as a function of the frequency dial rotation, by means of cam devices designed in accordance with correction formulae. Readout of effective RF capacitance is then automatically accomplished with the tuning of the oscillator.

Q Circuit Coupling

A simplified diagram of the Q circuit is shown in Figure 15. Input from the oscillator is inductively coupled to one side of the high stator on the Q capacitor, and the output from the capacitor is capacitively coupled from the opposite side of the high stator to the detector. The high stator serves as a shield between the input which is a current probe, and the output which is a voltage probe.

Output from the oscillator is terminated in the adjustable probe of a waveguide-below-cutoff type piston attenuator. This probe is a 50-ohm termination, resulting in a low standing wave ratio on the oscillator output line. A small loop at the end of the attenuator tube couples to a 50-ohm line which in turn enters the Q capacitor enclosure. The line is shorted near the terminals of the Q capacitor with a small loop which couples to the Q circuit. The entire transmission line is very short and nearly lossless and resonates at approximately 1400 Mc. Since the attenuator piston is loosely coupled, negligible loss is injected into the Q circuit.

The voltage probe consists of a 1N82 diode coupled very loosely as a capacitive probe to the high stator. This diode looks like 4500 ohms in parallel with 0.5 pf capacitance at 200 Mc. The very small coupling capacitor acts as a voltage divider in conjunction with the diode capacitance. This provides a voltage ratio of 25 to 2 and raises the effective resistance by a ratio of 156 to 1. The diode appears across the Q circuit as roughly 0.7 megohms, limiting the Q of the Q capacitor to somewhat over 3,500, which is considerably higher than the Q of small components suitable for measurement at the Q capacitor terminals.

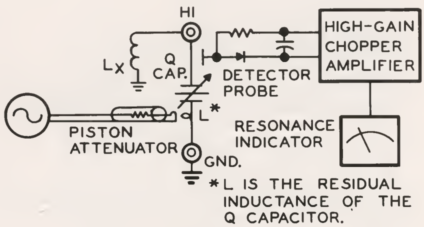


Figure 15. Simplified Q circuit

VOLTMETER SYSTEM

Output from the diode probe is approximately 20 μv dc when the resonant peak voltage is 0.025 volts rms. In order to utilize this low voltage level, a high-gain dc amplifier is necessary. The UHF Q Meter employs a photo-conductive chopper amplifier circuit for this purpose. This device makes use of light-sensitive resistance elements which are exposed to light interrupted periodically by a mask rotated by a synchronous motor. Tuned filters are used to remove noise, and synchronous detection is used to better the efficiency of recovery. This unit can be operated on a 50-cycle power source by merely changing a plug-in filter unit.

POWER SUPPLY

The power supply is an integral part of the instrument. A 300-volt, electronically regulated supply furnishes all of the power for the oscillator and the dc voltmeter circuit. Voltages for the voltmeter are supplied through a voltage divider. Two regulated dc power supplies are used to furnish power for the filaments: one for the oscillator, which has common cathode and heater connections, and the other for the constant-current pentode and low-level stages in the dc voltmeter. These dc supplies are transistor regulated with a Zener diode reference. Two 6.3-volt ac supplies are provided for noncritical filament and bulb lighting.

SECTION V

SOURCES OF ERROR

GENERAL

There are four factors which can cause errors in measurement on the UHF Q Meter. These are:

1. Errors due to the oscillator.
2. Errors due to the Q capacitor.
3. Errors due to the voltmeter.
4. External loading errors.

ERRORS DUE TO OSCILLATOR

The oscillator has a frequency accuracy of ±3%. The most significant error from this is that of determining inductance from resonating capacitance. Since $f_0 = \frac{1}{2\pi\sqrt{LC}}$, inductance is a function of f^2 and therefore a 3% frequency error can cause a 6% error in inductance. This can be entirely eliminated by use of a frequency counter connected to the monitor jack (J1).

Q is measured by determining the ratio $\frac{f_0}{\triangle f}$ for the 3 db bandwidth. This is read on an oscillator vernier which makes use of the fact that the frequency of the oscillator is a function of $e^{K\theta}$ where θ is the angular position of the oscillator rotor shaft.[1]. This means that a given angular increment is always the same percentage of center frequency anywhere in the oscillator rotation. This relationship is not perfect and typically causes errors of less than ±10%. External frequency measurement can improve this factor to the point where it is of no consequence.

The assumption is made that the oscillator level is constant during a measurement, while in fact, the level may change slightly during the traverse of the bandwidth. These changes are held so that typically they do not cause more than 5% error for Q's more than 50 and at most points less than 1%. However, if precise counter measurements are to be made it would be wise to check the output variation in the frequency range of interest with a good, well terminated (VSWR ≤ 1.1) RF voltmeter connected to the OSC jack (J3). This is particularly true for Q values below 50, where relatively wide frequency excursions are used.

ERRORS DUE TO Q CAPACITOR

The Q capacitor internal correction assumes that L x C is a constant; where C is the low frequency capacitance of the capacitor and L is the series inductance of the capacitor. The error due to this can be as high as ±(2% + 0.2 pf) at 600 Mc. Figure 17 is a plot of this error as a function of frequency for various values of capacitance.

1. "Design of a UHF Q Meter", Gorss, C. G., BRC Notebook No. 27, pages 3 and 4.

The low frequency capacitance value is held within ±2% of the nominal low frequency capacitance. This 98.81% of the capacitance reading at 210 Mc. To achieve better accuracy, an external calibration of low frequency capacitance must be made.

The Q Meter reads Q of the total resonating circuit. This includes the losses in the internal resonating capacitor, and its associated voltage probe. If the losses in the external test are very small it is possible that the losses in the internal capacitor account for more loss than the device being tested. The loss in the internal capacitor can be considered as a series resistance at a given frequency and capacitor setting. Figure 17 is a set of curves showing equivalent series resistance as a function of frequency for a representative series of capacitance values.

In addition to the series resistance, the resonating capacitor has a series inductance value which must enter into calculations involving Q inasmuch as energy is stored in this inductance. This inductance is given as a function of the low frequency capacitance in Figure 18. The equivalent circuit for calculations involving Q can then be regarded as the following:

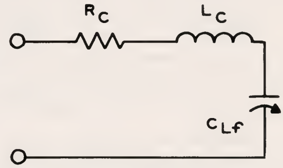


Figure 16. Equivalent circuit for Q calculations

wherever R_C is the equivalent series Resistance, L_C is the series inductance and C_{lf} is the low frequency capacitance.

In the case of an inductor placed on the terminals, L is measured in the conventional manner and recorded as L_1. Q is measured in the conventional manner. Q of the inductor is then computed from the following formula:

$$Q_1 = \frac{\omega_0 L_1 Q_t}{\omega_0 L_1 + \omega_0 L_C - Q_t R_C}. \quad (1)$$

$\omega_0 = 2\pi$ x frequency of measurement
L_1 = measured L
Q_t = measured Q
L_C = capacitor inductance from Figure 18
R_C = capacitor resistance from Figure 17

It must be kept in mind that the inductor must be attached directly to the resonating capacitor in the plane of the front panel to avoid any excess inductance. In addition, the inductor should be centrally located since mounting to the left or right of center will effectively increase the inductance.

In the case of a capacitor whose C and Q is to be measured, a work coil must first be placed on the terminals and resonated. Q is measured and recorded as Q_1. C is recorded from the dial as C_1, and the frequency is recorded as f_0. The capacitor is mounted in such a way as to reduce series L and not interfere with the work coil. Without changing frequency resonance is restored by adjusting the internal res-

onating capacitor. Q is read and recorded as Q_2. From the curves in Figures 17 and 18 determine R and L for the internal capacitor in both measurements. The first parameters shall be R_{C1} and L_{C1}. The second parameters shall be R_{C2} and L_{C2}.

Capacitance of the unknown is $C_1 - C_2$ or $\triangle C$. Q of the unknown is given by the expression:

$$Q\text{ cap} = \frac{Q_1Q_2\triangle C}{Q_1C_1^2\omega_0^2L_1 + Q_1\omega_0^2L_{C2}C_2^2 - Q_2\omega_0^2C_1^2(L_1 + L_{C1}) + Q_1Q_2\omega_0R_{C1}C_1^2 - R_{C2}Q_1Q_2\omega_0C_2^2} \quad (2)$$

where $\omega_0 = 2\pi f_0$.

In certain instances some of the terms in the denominator will be insignificant and may be dropped out. These must be judged on an individual basis. For example, where L_{C1} and L_{C2} are very small compared with L_1, they may be called zero. This would drop term 2 and simplify term 1 in the denominator. Where R_{C1} and R_{C2} are small compared with the losses in the external C, this entire expression can be replaced with:

$$\frac{Q_1Q_2(\triangle C)}{(Q_1 - Q_2)C_1}.$$

The previous expressions were derived from the fact that:

$$Q = \omega_0 \times \frac{\text{Energy Stored}}{\text{Avg. Power Dissipated}}. \quad (3)$$

This principle can be applied to any device connected to the terminals, whether distributed or lumped. The energy stored and dissipated in the internal capacitor can be derived from the given internal R and L figures.

ERRORS DUE TO VOLTMETER

The voltmeter is assumed to indicate the 3 db point on the resonance curve. If the ratio between the full scale and mid-scale point is not 3 db, the Q reading will be in error. This is held in practice to $\pm 2\%$. The method for checking the voltmeter calibration is given under "Detector Check" in Section VI.

EXTERNAL LOADING ERRORS

When measuring external resonators it is possible to couple one of the probes so closely that Q is reduced by its loading. It is good practice to make Q measurements at several different positions of each probe so that the effect of loading can be observed. Each probe should be decoupled to the point where further decoupling will not raise the indicated Q. It will often be necessary to use more sensitive ranges to perform this experiment.

SUMMARY

Summarizing, if the various sources of errors discussed above are to be taken into account, the following procedures should be performed in addition to the procedures given in Section III.

1. Use the frequency monitor jack (J1) and a frequency counter if the measurement requires better than 3% frequency accuracy.
2. Use the frequency monitor jack (J1) and a frequency counter if the measurement requires a Q accuracy of better than 15%.
3. Use an RF voltmeter to check the oscillator level change if a Q accuracy of better than 10% is required for Q values of less than 50 in general.
4. Use equation 1 when measuring the Q of inductors having a value of less than 20 nh or if extreme accuracy is required.
5. Use equation 2 when measuring the Q of capacitors with work coils having a value of less than 20 nh and capacitors with Q's higher than 100. If reduced

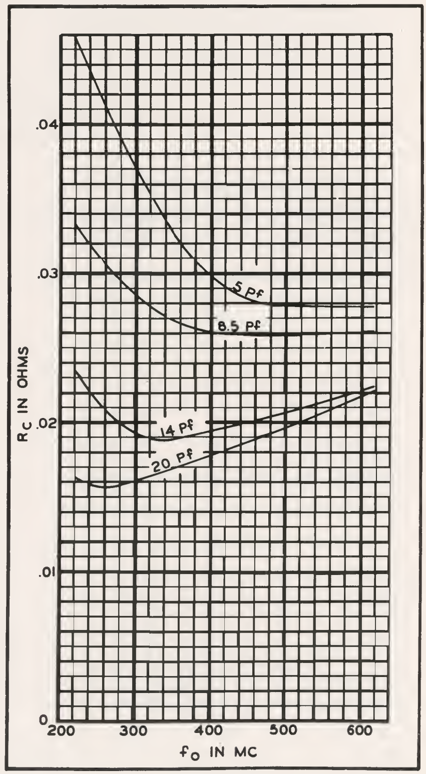


Figure 17. Curves showing equivalent series resistance of Q capacitor as a function of frequency

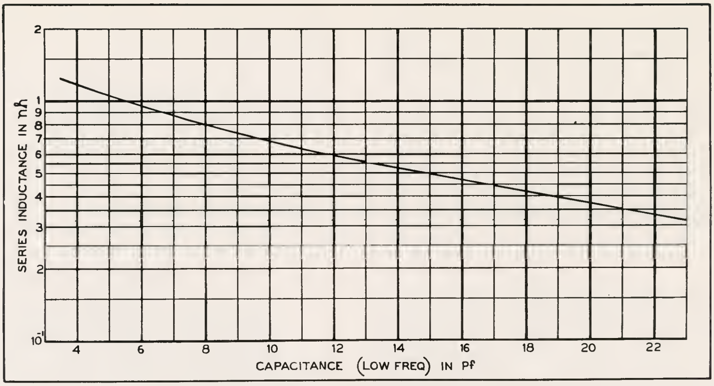


Figure 18. Curve showing series inductance of Q capacitor as a function of low frequency capacitance

accuracy is tolerable, use equation 3.

6. If refinement of the Q measurement is to be attempted beyond $\pm 2\%$, the 3 db ratio should be checked.

7. When making measurements with external probes, loading errors must be checked.

SECTION VI
MAINTENANCE

GENERAL

Maintenance performed on the UHF Q Meter should be limited to that work involved with replacing tubes and standard electrical components, and with performing the adjustment, calibration, disassembly, and assembly procedures necessitated by such component replacements. More extensive maintenance will result in the disturbance of adjustments and calibrations which can be made at the factory only with special equipment and techniques.

REPLACEMENT OF TUBES

All of the tubes in the UHF Q Meter are replaceable with commercially available tubes. When a fault is traced to a particular tube, that tube should be replaced and any necessary calibration and adjustment procedures should be performed. A list of the necessary calibration and adjustment procedures to be performed after component replacements is given below.

Component Replaced	*Calibration and Adjustments Required*
V1, 2, 3	Bias Adjustment (R47)
V4, 7, 8, 9	300-volt dc supply adjustment (R82, R106)
V10, 11	Calibration of Oscillator Circuit
CR14, TR2	6.3-volt dc supply adjustment (R86) Oscillator tube must be lighted.

DISASSEMBLY PROCEDURE

Most of the components in the UHF Q Meter are accessible after removal of the instrument cover. In order to gain access to components inside the oscillator shield and the voltmeter shield, and those components on the lower portion of the wired side of the main vertical chassis, it may be necessary to perform additional disassembly procedures. These procedures are given in the following paragraphs and should be used as required.

Note: *The instrument should be disconnected from the power source during disassembly and reassembly operations.*

Removing the Cover

To remove the cover from the instrument, proceed as follows:
1. Remove the two screws along the top edge of the front panel.
2. Remove the five screws along the bottom edge of the cover; two on each side, and one at the rear of the instrument.
3. Lift the cover off the instrument and pull the power cord through the cutout section in the rear of the cover.

Removal of the Main Vertical Chassis

To remove the vertical chassis at the rear of the instrument, proceed as follows:
1. Loosen the setscrews on the SENSITIVITY and ZERO control shaft couplers (the setscrews nearest the vertical chassis).
2. Disconnect the detector output cable (connector P9) from the Q capacitor (Figure 19).
3. Disconnect the cable (connector P8) at the right side of the low-pass filter (Figure 19).
4. Disconnect the jumper from the INJ (J2) connector at the rear of the instrument (Figure 2).
5. Remove the four screws that mount the INJ (J2) connector to the connector bracket and remove the connector and cable.
6. Remove the RF shield from the Q capacitor terminals.
7. Set the instrument on its carrying handles and remove the four screws, washers, and nuts that fasten the vertical chassis to the bottom plate.
8. Set the instrument back on its rubber feet, and remove the three screws, washers, and nuts that fasten the left and right side panels to the vertical chassis.
9. Remove the screws that fasten the vertical chassis to the two hexagonal support bars at the top left and right sides of the instrument.
10. Lift the chassis out of the notches in the support channels, and carefully pull it straight back until the SENSITIVITY and ZERO control shaft couplers are disengaged from their respective control shafts, and lay the chassis back so that it rests on the power transformer.
11. If it is necessary to gain access to the low-level voltmeter circuits, remove the six screws that fasten the cover to the voltmeter chassis and remove the cover. The SENSITIVITY and ZERO controls are removable with the cover.

Removal of the Oscillator Tube

In order to replace the oscillator tube and other components inside the oscillator, it will be necessary to remove the oscillator shield. To remove the shield, proceed as follows:
1. Remove the instrument cover according to the instructions given previously in this section.
2. Using a spring hook or a pair of longnose pliers, unhook the four helical springs that clamp the oscillator shield cover to the left side of the shield, and remove the shield cover. Hook the springs along the edge of the large hole cut into the instrument side panel until the cover is replaced.
3. Unsolder the four wires identified as "A", "B", "C", and "D" in Figure 20.
4. Remove the eleven screws and washers that mount the oscillator shield (Figure 20).
5. Carefully slide the oscillator shield to the left, past the butterfly and oscillator tube.
6. Loosen the screw on the clamp in the center of the oscillator tube and push it forward off the

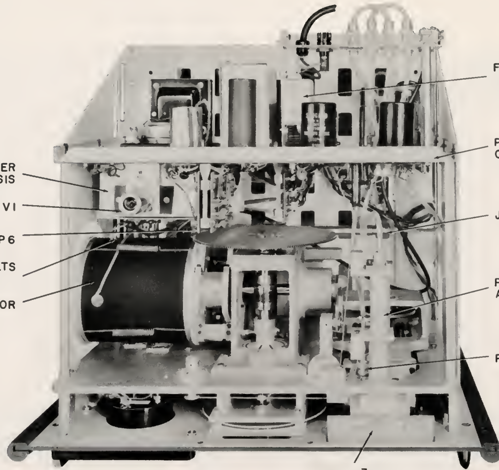


Figure 19. Type 280-A — Top view (cover removed)

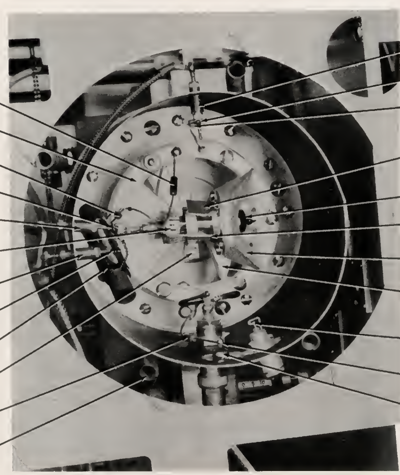


Figure 20. Oscillator assembly (shield cover removed)

spring fingers.
7. Slide the heater terminal and cathode assembly off the tube.
8. Remove the four screws that mount the tube support to the heat dissipation casting and slide the tube and socket toward the rear of the instrument, out of the hole in the casting.
9. Slide the clamp off the center of the tube. Be careful not to damage the spring fingers on capacitor C33.

Note: *After replacing the oscillator shield cover, set the SENSITIVITY switch to the most sensitive range, and scan the entire frequency range with the frequency control. The meter pointer should not deflect more than 3/8 of the full-scale indication. If greater deflection is noted, recheck the seating of the oscillator shield cover.*

CALIBRATION AND ADJUSTMENT PROCEDURES

The procedures and tolerances given in the following paragraphs reflect factory practice and are subject to change without notice.

Equipment Required

The following instruments are required for calibration and adjustment of the UHF Q Meter.
1. VTVM (H-P Model 410B or equivalent)
2. Precision capacitor measuring system
3. Frequency counter or other frequency measuring device (H-P Model 524C with Transfer Oscillator H-P Model 540B or equivalent)
4. VSWR indicator (Slotted Line — H-P Model 805A or equivalent)
5. Oscilloscope (H-P Model 130B or equivalent)
6. Variac
7. Signal Generator (BRC Type 225-A or equivalent)

Calibration of Oscillator Circuit

If the oscillator tube (V11) or the constant-current pentode (V10) is replaced, the voltages at the pins of V11 should be checked against the typical voltages given in the Voltage and Resistance Diagram (Figure 22), and the following procedure should be performed to check the operation of the oscillator.
1. Turn the power on and allow the instrument to warm up for at least 2 hours.
2. Connect a frequency counter or other frequency measuring device to the FREQ monitor jack (J1) at the rear of the instrument (Figure 2).
3. Set the HIGH CIRCUIT Q control 1¾ turns from either stop (pointer up).
4. Set the frequency control on the UHF Q Meter so that the frequency measuring device indicates 250 Mc. The MEGACYCLES dial on the Type 280-A should indicate within 3 Mc of 250 Mc.
5. To adjust, loosen the setscrews that fasten the MEGACYCLES dial to its shaft and adjust the dial on the shaft. Tighten the setscrews.
6. Turn the frequency control until the MEGACYCLES dial indicates 600 Mc. The frequency measuring device should indicate within ±3 Mc of 600 Mc. Adjust by means of the tab on the oscillator plate (Figure 20).
7. Check the frequency at all 50 Mc intervals on the MEGACYCLES dial. The dial should indicate within ±3% of the frequency indicated by the frequency measuring device at all points. If the oscillator is out of tolerance, the instrument should be returned to the factory for repair.

Calibration of Q Capacitor

The low frequency characteristics of the Q capacitor in the UHF Q Meter can be checked using the following procedure.

Adjustment of Movable Fiducial

Before checking the calibration of the Q capacitor, operation of the movable fiducial should be checked as follows.
1. Set the frequency control on the Type 280-A so that the MEGACYCLES dial indicates 210 Mc.
2. Adjust the L-C controls until the capacitance (pf) scale indicates 10.11 pf.
3. Turn the frequency control until the MEGACYCLES dial indicates 600 Mc. The capacitance (pf) scale on the L-C dial should read 10.97 pf.
4. If the movable fiducial does not indicate correctly, check the dial drive cord for wear.

Indicator Circuit Bias Adjustment

1. Set the ZERO control on the UHF Q Meter to the center of its travel.
2. Set the SENSITIVITY switch full counterclockwise for minimum sensitivity.
3. Adjust R47 (Figure 24) for zero reading on the resonance indicating meter.

Sensitivity Check

1. Connect a 50-ohm cable from the output terminal of a signal generator with a 50-ohm output impedance (such as the BRC Type 225-A) across the terminals of the Type 280-A Q capacitor.
2. Connect a 50-ohm resistor across the Q capacitor terminals.
3. Set the SENSITIVITY switch to the full clockwise position.
4. Set the Q capacitor for 4 pf.
5. Adjust the output of the signal generator for 25 millivolts at 500 Mc. The resonance indicating meter on the UHF Q Meter should indicate approximately full scale.
6. Set the SENSITIVITY switch to the full counterclockwise position.
7. Adjust the output of the signal generator for 250 millivolts at 500 Mc. The resonance indicating meter should indicate approximately full scale.

Amplifier Switching Check

1. Set the SENSITIVITY switch full counterclockwise.
2. Set the ZERO control full clockwise.
3. Turn the SENSITIVITY switch progressively clockwise to the next higher sensitivity range. The meter indication should increase approximately three times with each switching.

Amplifier Stability Check

1. Set the ZERO control for a mid-scale indication on the meter.
2. Observe the stability of the meter pointer for a five-minute period.
3. The pointer should remain stable with ½ inch.
4. If the stability is out of tolerance, check for noise on line or radiation from unshielded equivalent nearby. If this is not source of instability, change VI.
5. Check the —11-volt dc supply with a VTVM connected to the emitter terminal (purple wire) on TR3 (Figure 24). If the VTVM reads more than —12 volts, change CR15 (Figure 24).

Detector Check

To check the 3-db point of the diode monitor (CR16), proceed as follows.

1. Disconnect the jumpers at connectors J2 and J3 (Figure 2).
2. Using the necessary adapters, connect a 3 db pad between the oscillator output connector (J3) and the injection connector (J2).
3. Disconnect the 3db pad leaving only the adapters connected across J2 and J3.
4. Zero the Type 280-A meter with the ZERO control.
5. Adjust the frequency, Q capacitor, and LEVEL controls for a full-scale resonance indication on the meter.
6. Reinsert the 3 db pad.
7. The meter should read ½ scale within the tolerances specified below.

SENSITIVITY Control Setting	*Tolerance*
Ranges 1 and 2 (starting full counterclockwise)	±1/16 inch
Range 3	±⅛ inch
Range 4	±¼ inch
Range 5	±5/16 inch

8. After 1 minute, the VTVM should read 300 volts dc.
9. Rapidly vary the Variac setting from 105 to 125 volts. The VTVM indication should remain within ±0.1 volt of the 300-volt indication. If the reading on the VTVM exceeds this tolerance, disconect the VTVM and reconnect the oscilloscope, and slightly readjust R82 so that the trace on the oscilloscope remains stable (minimum transient).

6.3-Volt DC Supply

1. Connect a dc VTVM to the terminals protruding from the oscillator shield (Figure 19). Be careful not to short or ground the two terminals.
2. With a Variac connected between the UHF Q Meter and the power source, adjust the Variac for 115 volts ac.
3. The VTVM should read 6.3 volts dc. Adjust by means of R86 (Figure 23).
4. Disconnect the VTVM and connect an oscilloscope in its place. Ripple should be less than 50 millivolts.
5. Set Variac to 105 volts ac. Ripple should be less than 100 millivolts. If ripple is greater, change CR14 and recheck ripple.

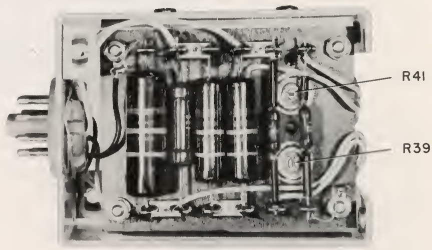
—11-Volt DC Supply

1. Connect the Type 280-A to the power source through a Variac.
2. Connect an oscilloscope to the emitter terminal on TR3 (purple wire) shown in Figure 24.
3. Set Variac for 105 volts ac.
4. Ripple, as indicated on the oscilloscope, should be less than 100 millivolts.
5. Set Variac to 115 volts ac.
6. Ripple should be less than 70 millivolts.
7. If ripple is excessive, or if the —11-volt supply is not within ±0.6 volt, as measured at this point with a VTVM, CR15 (Figure 24) should be replaced.

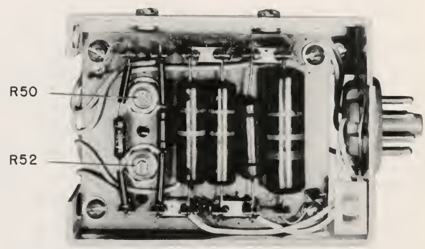
Adjustment of Twin "T" Filters

1. Remove the instrument cover. The filters are mounted on the rear vertical chassis (Figure 24).

2. The two filters are contained in a single plug-in unit which is held by two retaining screws on either side of the unit. Remove the unit.



Left Side View



Right Side View

Figure 21. Twin "T" filter

3. Connect a harmonic-free sinewave with a frequency of exactly 5/6 of the power-line frequency between pins 6 and 8 on the filter plug base.

4. Connect an oscilloscope or VTVM between pins 7 and 8 on the filter plug base.

5. Compare the signal amplitude with the amplitude of the applied signal. If the attenuation is approximately 60 db, the filter is properly adjusted.

6. If there is insufficient attenuation, remove the U-shaped cover from the unit. The cover is secured by four screws; one on each side and two on top.

7. Alternately adjust R39 and R41 for minimum signal between pins 7 and 8. The potentiometers are located on the left side (viewed from rear) when the filter unit is plugged in (Figure 21). On "potted" filters use blue adjustments.

8. Repeat the procedure for the other filter, connecting the test signal between plug pins 3 and 8, and the oscilloscope or VTVM between 2 and 8. Alternately adjust potentiometers R50 and R52 for minimum signal between plug pins 7 and 8. The potentiometers are located on the right side (viewed from the rear) when the filter unit is plugged in (Figure 21). On "potted" filters use red adjustments.

Low Frequency Check of Q Capacitor

The low frequency calibration of the Q capacitor can be checked using a precision capacitance measuring system capable of measuring a capacitance of 4 pf to $\pm 1\%$ or better in the frequency range of 10 to 100 kc.

1. Set the frequency control on the Type 280-A for 210 Mc.

2. Set the capacitance (pf) dial to 4 pf.

3. Measure the capacitance with the precision capacitance system at the Q capacitor terminals.

4. At 210 Mc the capacitance dial has a built-in correction factor of $+1.2\%$. This should be taken into account with the accuracy of the precision measuring system in determining the overall accuracy of the measurement.

5. Repeat the procedure with the capacitance dial on the UHF Q Meter set to 10 and 25 pf.

Note: *If the Q capacitor is out of calibration the instrument should be returned to the factory for calibration. Field calibration of the Q capacitor should not be attempted.*

TROUBLE SHOOTING

Data, including voltage and resistance charts, a trouble-shooting chart, and an overall schematic diagram (Figure 26) have been included in these instructions as an aid to trouble shooting. The troubles given in the Trouble-shooting Chart are only the common troubles which might be encountered, and the causes cited are the probable causes for these troubles. It should be noted that other defective components in the affected circuits could be the cause of the malfunctioning of the instrument.

Most troubles will be the result of tube failure. For this reason, it is recommended that one of the first steps in the trouble-shooting procedure consist of an inspection of the tubes for lighted filaments. If all filaments are lighted, the tubes in the stage or circuit believed to be malfunctioning should be checked in a tube tester before further steps are taken.

TROUBLE-SHOOTING CHART

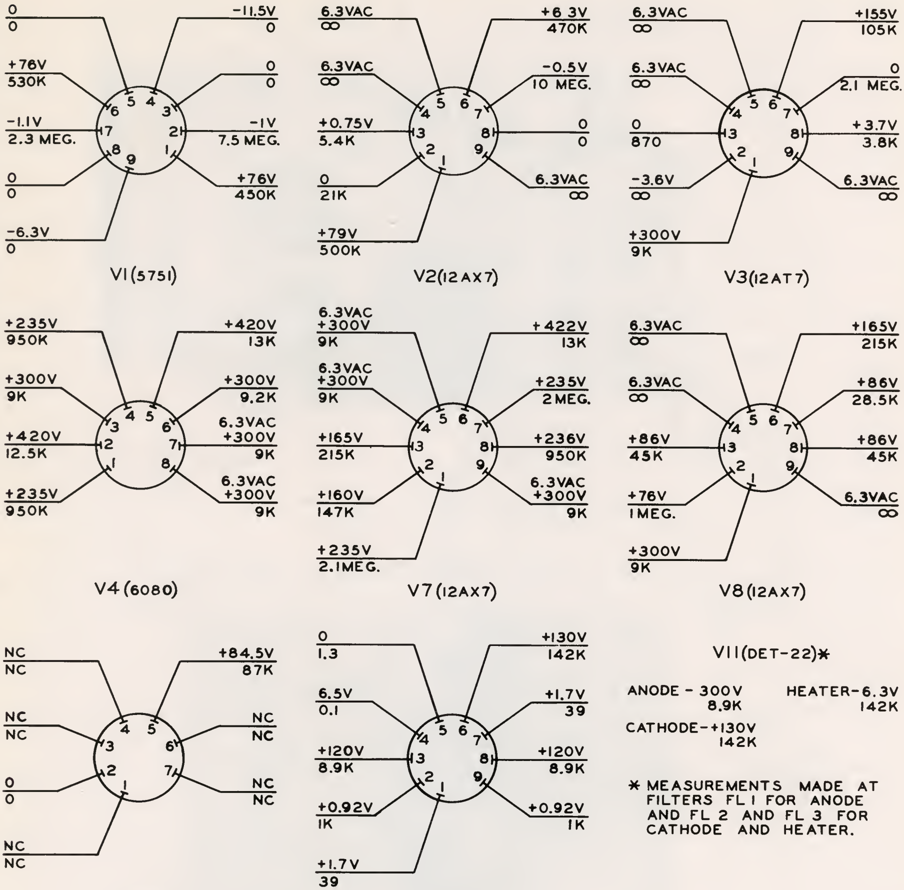
Symptom	*Probable Cause*	*Remedy*
1. Meter will not zero.		
All positions of SENSITIVITY switch.	R47 (Bias) out of adjustment or defective.	Adjust per "Calibration of Indicator Circuit" procedure or replace.
	Tube V3B defective.	Replace tube.
	ZERO control R30 defective.	Replace control.
One position of SENSITIVITY switch.	Open contact in sections 2 or 3 of SENSITIVITY switch S2.	Repair open.
2. Meter will not peak at full scale.	Defective tube in amplifier circuit.	Replace tube. Perform "Amplifier Gain and Stability Checks."
	Defective oscillator tube V11 or constant-current pentode V10.	Replace tube. Perform "Calibration of Oscillator" procedure.
3. Meter will not indicate resonance.	Jumpers not in place at rear of instrument.	Connect jumpers (Figure 2).
	Q of test component not in range of instrument.	Select component in range of instrument. (See Q range under Specifications.)
	Defective component in oscillator circuit.	Replace defective component. Perform "Calibration of Oscillator" procedure.
	Defective component in amplifier circuit.	Replace defective component. Perform "Amplifier Gain and Stability Checks."
	Defective component in power supply.	Replace defective component. Check "Power Supply Adjustments."
4. Meter drifts.	Defective tube in amplifier circuit.	Replace defective tube. Perform "Amplifier Gain and Amplifier Stability Checks."

Symptom	*Probable Cause*	*Remedy*
	Defective tube in power supply circuit.	Replace defective tube. Check "Power Supply Adjustments."
	Defective oscillator tube V11.	Replace defective tube. Perform "Calibration of Oscillator" procedure.
	Thermal Voltages	Locate instrument in constant temperature environment.
5. Meter is sluggish.	Chopper bulb (DS2 — DS5) burned out.	Replace bulb.
	Twin "T" filter (FL5) not tuned for maximum rejection.	See procedure for adjustment of Twin "T" filter.
6. Response but no resonance indication when tuning through MEGACYCLES dial on most sensitive range.	Leakage from oscillator.	Check to see that oscillator cover is secure. Twist to seat fully.
	External source of rf or noise on line.	
7. Range of ZERO control not centered on least sensitive range.	Bias (R47) out of adjustment.	See Indicator Bias Adjustment.
	Thermal voltages.	External equipment should be near same temperature as Type 280-A, as instrument is sensitive to small thermal changes on more sensitive ranges.
8. Meter goes off scale with no signal.	Bias (R47) out of adjustment.	See Indicator Bias Adjustment.
	DC short between chassis and circuit ground.	Check for short with power off and diode cable disconnected at rear of Q capacitor (Figure 19).
9. Meter pointer wanders off zero indication by more than ¼ inch on most sensitive range.	V1 noisey.	Replace V1.
10. Meter responds to signal and bias (R47) but not to ZERO control.	Short inside shielded indicator chassis (Figure 19).	Locate and repair short.

SOCKET VOLTAGE AND RESISTANCE MEASUREMENTS

The socket voltages and resistances given in the Voltage and Resistance Diagram were measured with an H-P Model 410B VTVM. Except for the filament voltages, all voltages were measured between the tube socket pin and the ground buss. Line voltage during the measurements was maintained at 120 volts ac. Control settings for both voltage and resistance measurements were as follows.

Control	*Setting*
SENSITIVITY Switch	Minimum sensitivity (full counterclockwise)
LEVEL	Full counterclockwise
ZERO	Adjusted for zero indication on meter
CIRCUIT Q	Infinity (∞)
HIGH CIRCUIT Q	Infinity (∞)
Frequency (MEGACYCLES)	300 Mc
L-C Dial (Frequency Scale)	300 Mc



NOTES

1. VOLTAGES ARE DC UNLESS OTHERWISE NOTED.
2. RESISTANCE IS IN OHMS.
3. V1 VIEWED FROM COMPONENT SIDE. ALL OTHERS VIEWED FROM WIRING SIDE.

Figure 22. Voltage and resistance diagram

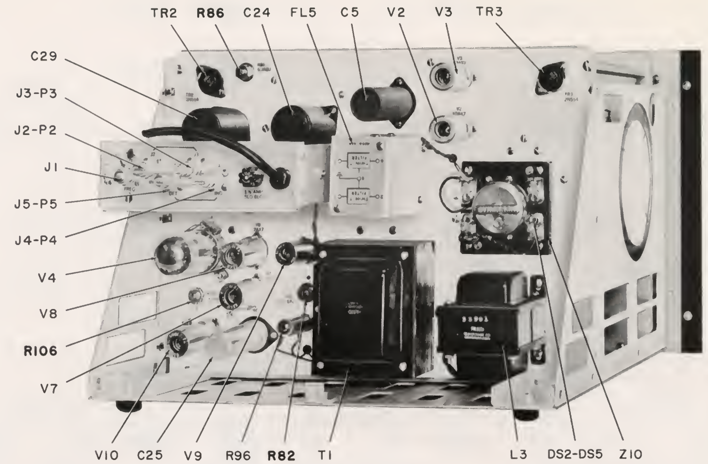


Figure 23. Type 280-A Rear view (cover removed)

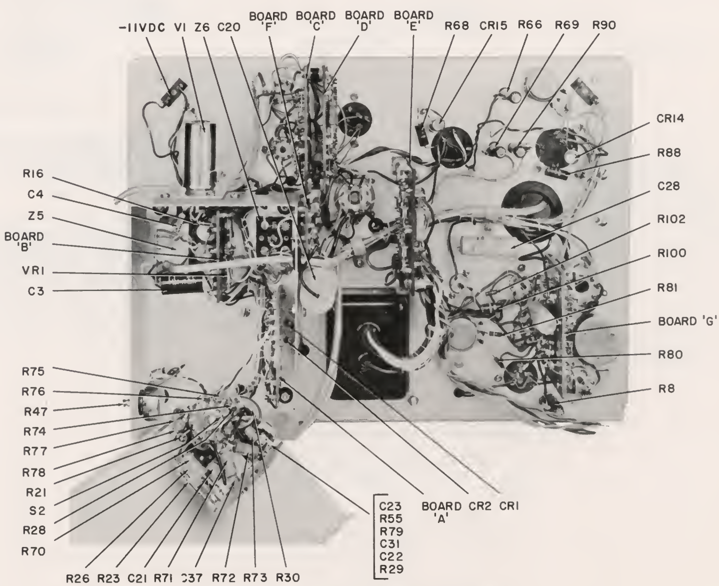


Figure 24. Type 280-A Power supply chassis
(See Figure 25 for terminal board details)

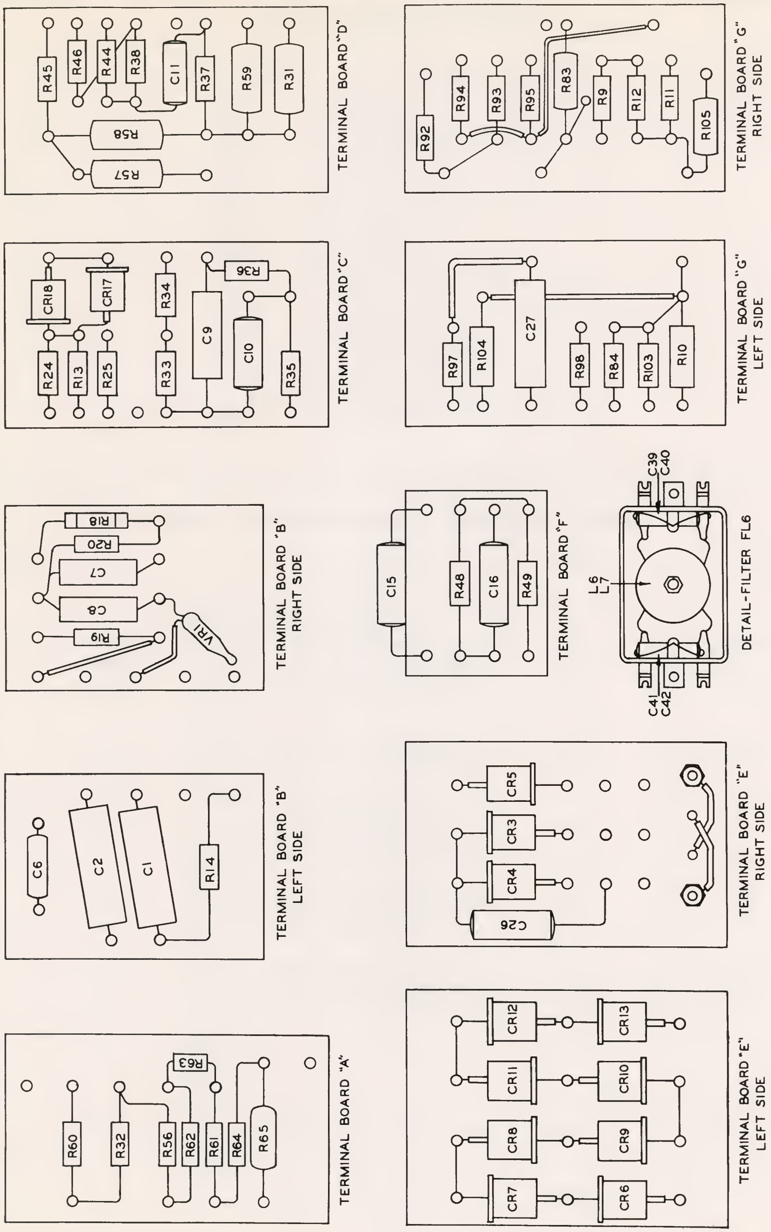


Figure 25. Terminal board details (see Figure 24)

LIST OF MANUFACTURERS

Abbreviation	*Manufacturer's Name*
AB	Allen-Bradley Co.
AER	Aerovox Corp.
AH	Arrow-Hart & Hegeman Electric Co.
BUSS	Bussmann Mfg. Division, McGraw-Edison Co.
CD	Cornell-Dublier Electric Corp.
CGW	Corning Glass Works
CTS	Chicago Telephone Supply Corp.
DEC	Dage Electric Co., Inc.
DPI	Dale Products, Inc.
FRC	Freed Transformer Co., Inc.
GA	Good-All Electric Mfg. Co.
GE	General Electric Co.
GEN	Genalex Division, British Industries Corp.
H-P	Hewlett-Packard Co.
IPC	Industrial Products Co.
IRC	International Resistance Co.
OMC	Ohmite Mfg. Co.
RCA	Radio Corp. of America.
SLE	Sylvania Electric Products, Inc.
WAL	Ward-Leonard Co.

TABLE OF REPLACEABLE ELECTRICAL PARTS

Circuit Symbol	*Value*	*Description*	*BRC Part No.*	*Mfg.*	*Mfg's. Type No.*
AT1		Piston Attenuator Assembly	307269		
B1		P/O Chopper Assembly (Z10)			
C1-C3	0.1 μf	Capacitor: Fixed, Polystyrene, ±10%, 100 vdcw	82451	GA	820UB
C4	4700 pf	Capacitor: Fixed, Mylar, ±10%, 600 vdcw	82336	GA	620M
C5AB	20-20 μf	Capacitor: Fixed, Electrolytic, 450 vdcw	83140	CD	UP-2245
C6	0.01 μf	Capacitor: Fixed, Mylar, ±20%, 400 vdcw	82441	GA	620M
C7		Same as C4			
C8		Same as C6			
C9	0.1 μf	Capacitor: Fixed, Mylar, ±10%, 600 vdcw	82447	GA	620M
C10	0.047 μf	Capacitor: Fixed, Mylar, ±10%, 600 vdcw	82445	GA	620M
C11		Same as C6			
C12-C14		P/O Twin "T" Filter Assembly (FL5)			
C15,C16	0.027 μf	Capacitor: Fixed, Mylar, ±10%, 600 vdcw	82442	GA	620M
C17-C19		P/O Twin "T" Filter Assembly (FL5)			
C20	2 μf	Capacitor: Fixed, Mylar ±20%, 300 vdcw	83126	GA	663A
C21		Same as C15			
C22	0.1 μf	Capacitor: Fixed, Mylar, ±5%, 200 vdcw	82446	GA	620M
C23	2200 pf	Capacitor: Fixed, Mylar, ±10%, 600 vdcw	82335	GA	620M
C24	1000 μf	Capacitor: Fixed, Electrolytic, 25V	83144	AER	1-10AFH
C25AB		Same as C5			
C26	0.033 μf	Capacitor: Fixed, Mylar, ±10%, 600 vdcw	82444	GA	620M
C27	0.25 μf	Capacitor: Fixed, Mylar, ±2%, 400 vdcw	83104	GA	620M
C28	1 μf	Capacitor: Fixed, Mylar, ±20%, 200 vdcw	83142	GA	620M
C29		Same as C24			
C30		Special			
C31		Same as C26			
C32		Special			
C33		Special			
C34		Special			
C35	100 pf	Capacitor: Fixed, Ceramic, Standoff ±20%, 500 vdcw	82153	AB	SS5A-101W
C36		Special			
C37		Same as C9			
C38	1000 pf	Capacitor: Fixed, Ceramic, GMV tol	307640		

Circuit Symbol	*Value*	*Description*	*BRC Part No.*	*Mfg.*	*Mfg's. Type No.*
C39-C42		Same as C15			
CR1,CR2		Diode, Zener	98000	H-P	G-31A-7H
CR3,CR4		Rectifier, Silicon: 0.5 amps, 400V	91100	RCA	1N1763
CR5		Rectifier, Silicon: 0.75 amp, 50V	98004	RCA	1N536
CR6-CR13		Same as CR3			
CR14		Diode, Zener	98002	H-P	G-31G-7H
CR15		Diode, Zener	98001	H-P	G-31G-12L
CR16		Diode, Silicon	306241	SLE	1N82
CR17,CR18		Same as CR3			
DS1		Lamp, Incandescent: 0.15 amp, 6-8V, #47	90904	GE	#47
DS2-DS5		Lamp, Incandescent: 6-8V, 2 pin base, #12	90910	GE	#12
F1		Fuse, Cartridge: Fusetron, ½ amp, 125V, slow blowing	95031	BUSS	MDL
		Fuse, Cartridge: Fusetron, ¾ amp, 250V, slow blowing		BUSS	MDL
FL1-FL3		Filter: Low-pass, high-freq, feed-thru	82452	AB	F1S
FL4		Filter: Low-pass: 1000 Mc	307434		
FL5		Filter, Twin "T": 60 cycles	306725	H-P	425A-42A
		Filter, Twin "T": 50 cycles		H-P	425A-42B
FL6		Filter, RF	307330		
J1-J5		Jack, BNC: RF Connector, UG-291/U	89065	IPC	5000
J6		Jack, BNC: RF Connector, UG-909/U	306757	IPC	86025
J8		Jack, BNC: RF Connector, UG-89B/U	94068	DEC	415-1
L1-L2		Coil, RF	307506		
L3	2-12h	Choke, Filter	307503	FRC	33901
L4		Special			
L5		Special			
L6,L7		Choke, RF	305358		
M1		Meter: 1.0 ma. full scale	306760		
P1		Power Cord: 115V, 8 ft., includes plug	01019		
P2-P7		Plug, BNC: RF Connector, UG-88/U	94156	IPC	1200
P8		Same as P2			
R1,R2	100Ω	Resistor: Fixed, Composition, ±5%, ½W	80062	AB	EB
R3	1KΩ	Resistor: Fixed, Composition, ±5%, ½W	80148	AB	EB
R4	7.5KΩ	Resistor: Fixed, Composition, ±5%, ½W	80397	AB	EB
R5	50Ω	Resistor: Fixed, Deposited Carbon, ±1%, ⅛W	80233	DPI	DC⅛
R6	50Ω	Resistor and End Cap Assembly	80046		
R7	50KΩ	Resistor: Fixed, Film, ±5%, ¼W	80445	IRC	HFR
R8	10KΩ	Resistor: Fixed: Wirewound, ±5%, 5W	80749	WAL	Vitrohm 5F
R9	150KΩ	Resistor: Fixed, Composition, ±5%, ½W	80564	AB	EB
R10	15KΩ	Resistor: Fixed, Composition, ±5%, 2W	80338	AB	HB
R11	39Ω	Resistor: Fixed, Composition, ±5%, ½W	80031	AB	EB
R12		Same as R3			
R13	1.5KΩ	Resistor: Fixed, Composition, ±5%, ½W	80273	AB	EB
R14	3.3KΩ	Resistor: Fixed, Composition, ±5%, ½W	80253	AB	EB
R15	2.5KΩ	Resistor: Variable, ±20%, ½W	81085		
R16	6.8 Meg.Ω	Resistor: Fixed, Composition, ±5%, ½W	80642	AB	EB
R17		This circuit symbol not assigned			
R18	405KΩ	Resistor: Fixed, Deposited Carbon ±1%, ½W	80751	Aerovox	CP½
R19	2.2 Meg.Ω	Resistor: Fixed, Composition, ±5%, ½W	80649	AB	EB
R20	470KΩ	Resistor: Fixed, Composition, ±5%, ½W	80640	AB	EB
R21	10KΩ	Resistor: Fixed, Film, ±5%, 2W	80747	CGW	C-42
R22		This circuit symbol not assigned			
R23	100Ω	Resistor: Fixed, Composition, ±5%, 2W	80770	AB	EB
R24	150Ω	Resistor: Fixed, Composition, ±5%, ½W	80098	AB	EB
R25		Same as R3			
R26	22KΩ	Resistor: Fixed, Film, ±5%, 2W	80753	CGW	C-42
R27		This circuit symbol not assigned			
R28	680KΩ	Resistor: Fixed, Composition, ±5%, ½W	80663	AB	EB
R29	1 Meg.Ω	Resistor: Fixed, Composition, ±5%, ½W	80621	AB	EB
R30	1 Meg.Ω	Resistor: Variable, ±20%, 2W	81618	AB	J
R31		Same as R21			

Circuit Symbol	*Value*	*Description*	*BRC Part No.*	*Mfg.*	*Mfg's. Type No.*
R32		Same as R29			
R33		Same as R20			
R34	47KΩ	Resistor: Fixed, Composition, ±5%, ½W	80460	AB	EB
R35	5.6KΩ	Resistor: Fixed, Composition, ±5%, ½W	80376	AB	EB
R36	10 Meg.Ω	Resistor: Fixed, Composition, ±5%, ½W	80741	AB	EB
R37		Same as R20			
R38		Same as R19			
R39-R43		P/O Twin "T" Filter Assembly (FL5)			
R44		Same as R3			
R45	100KΩ	Resistor: Fixed, Composition, ±5%, ½W	80517	AB	EB
R46	3.9KΩ	Resistor: Fixed, Composition, ±5%, ½W	80287	AB	EB
R47	10KΩ	Resistor: Variable, Composition, ±20%, 2W	81336	AB	JL
R48		Same as R16			
R49	82KΩ	Resistor: Fixed, Composition, ±5%, ½W	80554	AB	EB
R50-R54		P/O Twin "T" Filter Assembly (FL5)			
R55	22 Meg.Ω	Resistor: Fixed, Composition, ±5%, ½W	80742	AB	EB
R56	10KΩ	Resistor: Fixed, Composition, ±5%, ½W	80361	AB	EB
R57	2.7KΩ	Resistor: Fixed, Film, ±5%, 2W	80745	CGW	C-42
R58	6.8KΩ	Resistor: Fixed, Film, ±5%, 2W	80746	CGW	C-42
R59	47KΩ	Resistor: Fixed, Composition, ±5%, 2W	80494	AB	HB
R60	390KΩ	Resistor: Fixed, Composition, ±5%, ½W	80664	AB	EB
R61		Same as R29			
R62	8.2KΩ	Resistor: Fixed, Composition, ±5%, ½W	80326	AB	EB
R63	220KΩ	Resistor: Fixed, Composition, ±5%, ½W	80555	AB	EB
R64		Same as R56			
R65	2.2KΩ	Resistor: Fixed, Film, ±5%, 2W	80744	CGW	C-42
R66	7.5Ω	Resistor: Fixed, Wirewound, ±10%, 10W	80748	OMC	"Brown Devil"
R67		This circuit symbol not assigned			
R68	220Ω	Resistor: Fixed, Composition, ±5%, 2W	80414	AB	HB
R69	3Ω	Resistor: Fixed, Wirewound, ±10%, 5W	80043	OMC	"Brown Devil"
R70		Same as R59			
R71	150KΩ	Resistor: Fixed, Film, ±5%, 2W	80507	CGW	C-42
R72	270KΩ	Resistor: Fixed, Film, ±5%, 2W	80755	CGW	C-42
R73	560KΩ	Resistor: Fixed, Film, ±5%, 2W	80757	CGW	C-42
R74	9.1KΩ	Resistor: Fixed, Film, ±5%, 2W	80752	CGW	C-42
R75	33KΩ	Resistor: Fixed, Film, ±5%, 2W	80754	CGW	C-42
R76	100KΩ	Resistor: Fixed, Film, ±5%, 2W	80509	CGW	C-42
R77	330KΩ	Resistor: Fixed, Film, ±5%, 2W	80756	CGW	C-42
R78	1 Meg.Ω	Resistor: Fixed, Film, ±5%, 2W	80758	CGW	C-42
R79		Same as R55			
R80	75KΩ	Resistor: Fixed, Composition, ±5%, ½W	80508	AB	EB
R81	270KΩ	Resistor: Fixed, Composition, ±5%, ½W	80604	AB	EB
R82	25KΩ	Resistor: Variable, Composition, ±10%, 2W	81028	AB	JL
R83	82KΩ	Resistor: Fixed, Composition, ±5%, 2W	80569	AB	HB
R84	330KΩ	Resistor: Fixed, Composition, ±5%, ½W	80651	AB	EB
R85		This circuit symbol not assigned			
R86	200Ω	Resistor: Variable, Composition, ±10%, 2W	81131	AB	JL
R87,R89		These circuit symbols not assigned			
R88	120Ω	Resistor: Fixed, Composition, ±5%, 2W	80743	AB	HB
R90	2Ω	Resistor: Fixed, Wirewound, ±10%, 5W	80773	OMC	"Brown Devil"
R91		This circuit symbol not assigned			
R92,R93	10Ω	Resistor: Fixed, Composition, ±5%, ½W	80006	AB	EB
R94,R95		Same as R3			
R96	15KΩ	Resistor: Fixed, Wirewound, ±5%, 20W	80750	WAL	20F
R97		Same as R63			
R98		Same as R19			
R99		This circuit symbol not assigned			
R100	82KΩ	Resistor: Fixed, Composition, ±5%, 2W	80569	AB	HB
R101		This circuit symbol not assigned			
R102,R103		Same as R29			
R104	47KΩ	Resistor: Fixed, Composition, ±5%, 2W	80494	AB	HB
R105		Same as R75			
R106	5KΩ	Resistor: Variable, Wirewound, ±10%, 4W	81333	CTS	25

TABLE I

FORMULAS FOR CALCULATING Q AND IMPEDANCE PARAMETERS FROM PARALLEL AND SERIES MEASUREMENTS

LUMPED-PARAMETER CIRCUITS

Parallel Measurements

Effective Q of Unknown

$$Q = \frac{Q_1 Q_2 (C_2 - C_1)}{\Delta Q C_1} \qquad (8)$$

Effective Parallel Resistance of Unknown

$$R_p = \frac{Q_1 Q_2}{\omega C_1 \, \Delta Q} \qquad (5)$$

Effective Parallel Reactance of Unknown

$$X_p = \frac{1}{\omega (C_2 - C_1)} \qquad (6)$$

Effective Parallel Inductance of Unknown

$$L_p = \frac{1}{\omega^2 (C_2 - C_1)} \qquad (9)$$

Effective Parallel Capacitance of Unknown

$$C_p = C_1 - C_2 \qquad (7)$$

Note 1: In Eq. (6) the sign of the quantity $(C_2 - C_1)$ indicates the type of effective reactance. A positive quantity results from an inductive reactance and a negative sign from a capacitive reactance.

Note 2: Disregard the sign of the quantity $(C_2 - C_1)$ in Eq. (8) above.

Series Measurements

Effective Q of Unknown

$$Q = \frac{Q_1 Q_2 (C_1 - C_2)}{C_1 Q_1 - C_2 Q_2} \qquad (13)$$

Effective Series Resistance of Unknown

$$R_s = \frac{\left(\frac{C_1}{C_2}\right) Q_1 - Q_2}{\omega C_1 Q_1 Q_2} \qquad (10)$$

Effective Series Reactance of Unknown

$$X_s = \frac{C_1 - C_2}{\omega C_1 C_2} \qquad (11)$$

Effective Series Inductance of Unknown

$$L_s = \frac{C_1 - C_2}{\omega^2 C_1 C_2} \qquad (12)$$

Effective Series Capacitance of Unknown

$$C_s = \frac{C_1 C_2}{C_2 - C_1} \qquad (14)$$

Note 1: In Eq. (11) the sign of the quantity $(C_1 - C_2)$ indicates the type of effective reactance. A positive quantity results from an inductive reactance and a negative sign from a capacitive reactance.

Note 2: Disregard the sign of the quantity $(C_1 - C_2)$ in Eq. (13) above.

TABLE II

FORMULAS RELATING SERIES AND PARALLEL COMPONENTS

$$Q = \frac{X_s}{R_s} = \frac{\omega L_s}{R_s} = \frac{1}{\omega C_s R_s} = \frac{R_p}{X_p} = \frac{R_p}{\omega L_p} = R_p \omega C_p = \frac{\sqrt{\frac{L}{C}}}{R_s} = \frac{R_p}{\sqrt{\frac{L}{C}}}$$

General Formulas	Formulas for Q greater than 10	Formulas for Q less than 0.1	General Formulas	Formulas for Q greater than 10	Formulas for Q less than 0.1
$R_s = \frac{R_p}{1 + Q^2}$	$R_s = \frac{R_p}{Q^2}$	$R_s = R_p$	$R_p = R_s(1 + Q^2)$	$R_p = R_s Q^2$	$R_p = R_s$
$X_s = X_p \frac{Q^2}{1 + Q^2}$	$X_s = X_p$	$X_s = X_p Q^2$	$X_p = X_s \frac{1 + Q^2}{Q^2}$	$X_p = X_s$	$X_p = \frac{X_s}{Q^2}$
$L_s = L_p \frac{Q^2}{1 + Q^2}$	$L_s = L_p$	$L_s = L_p Q^2$	$L_p = L_s \frac{1 + Q^2}{Q^2}$	$L_p = L_s$	$L_p = \frac{L_s}{Q^2}$
$C_s = C_p \frac{1 + Q^2}{Q^2}$	$C_s = C_p$	$C_s = \frac{C_p}{Q^2}$	$C_p = C_s \frac{Q^2}{1 + Q^2}$	$C_p = C_s$	$C_p = C_s Q^2$

Circuit Symbol	*Value*	*Description*	*BRC Part No.*	*Mfg.*	*Mfg's. Type No.*
S1		Switch, Toggle: DPDT	88059	AH	81027CE
S2		Switch, Rotary: 3 Section, 5 Position	306756		
T1		Transformer, Power	306720		
TR1		This circuit symbol not assigned			
TR2,TR3		Transistor: PNP, 10W	98500	SLE	2N554
V1AB		Tube, Electron: 5751			
V2AB		Tube, Electron: 12AX7			
V3AB		Tube, Electron: 12AT7			
V4		Tube, Electron: 6080			
V5,V6		These circuit symbols not assigned			
V7,V8		Tube, Electron: 12AX7			
V9		Tube, Electron: 5651			
V10		Tube, Electron: 6CL6			
V11		Tube, Electron: DET-22		GEN	
VR1		Lamp, Glow: 1/25W, wire term. base	303623	GE	NE-2
Z1-Z4		These circuit symbols not assigned			
Z5		Modulator Assembly	306726	H-P	425A-23A
Z6		Demodulator Assembly	307336	H-P	425A-23B
Z7		This circuit symbol not assigned			
Z8		Special			
Z9		Special			
Z10		Chopper Assembly	306724	H-P	425A-97A

BIBLIOGRAPHY

Many measuring techniques have evolved around the Q Meter since its introduction by the Boonton Radio Corporation in 1934. While these measurements are too specialized to present in an instruction book, it was considered desirable to include a bibliography of Q Meter measurements and related subjects. We will welcome having any omissions brought to our attention and invite correspondence concerning new applications for Q Meters.

The Boonton Radio Corporation is indebted to those engineers and technicians whose contributions to the literature have advanced the art of Q Meter measurements and wish to offer our thanks to the entire engineering profession for the world-wide acceptance given to BRC Q Meters.

GENERAL Q METER THEORY (CALIBRATION AND CORRECTION OF ERRORS)

V. V. K. Rao, "The Q Meter and Its Theory," Proc. I.R.E., p. 502; Nov., 1942.

I. Bady, "Calibration of Q Meter, Model 160-A," Signal Corps Report, March, 1943.

W. F. Lovering, "On the Measurement of the Residual Parameters of a Q Meter," Philo. Mag., Feb., 1944.

Aircraft Radio Laboratory Engineering Report No. 371 (War Department), "Derivation of Q Meter Formulae and Limits of Application to Fixed Frequency Impedance Measurements," August, 1944.

D. M. Hill, "Measurement of the Internal Inductance of the Q Meter Circuit of the 160-A Q Meter," BRC Report No. 1549, Oct., 1944.

I. Bady, "Notes on Increasing the Accuracy and Usefulness of the Boonton Q Meter Model 160-A," Signal Corps Report, Sept., 1945.

G. F. Barnett, "Method for Extending Range of Q Meter," Elect. World, p. 78, March, 1946.

H. G. M. Spratt, "Q Meters," Wireless World, p. 7, Jan., 1949.

A. C. Lynch, "Improved Accuracy with a Q Meter by the Use of Auxiliary Components," Elect. Eng., p. 91, March, 1949.

Cathode Ray, "Q — How Many Kinds Are There?", Wireless World, p. 267, July, 1949.

R. E. Lafferty, "Q Meter Correction Chart for Q Voltmeter Loading," p. 43, Tele-Tech, Oct., 1952.

R. E. Lafferty, "Q Meter Correction Chart for Distributed Capacitance," p. 63, Tele-Tech, Nov., 1952.

Bureau of Standards Circular C-47, "Radio Instruments and Measurements," p. 133.

R. F. Field and D. B. Sinclair, "A Method for Determining the Residual Inductance and Resistance of a Variable Air Condenser at Radio Frequencies," Proc. I.R.E., Feb., 1936.

R. G. Medhurst, "HF Resistance and Self-Capacitance of Single-Layer Solenoid," Wireless Engineer, Feb. and March, 1947.

Q MEASUREMENTS

C. J. Franks, "Values of Q for Various Component Parts," Electronics, p. 126, April, 1935.

A. W. Barber, "The Resultant Q of Tuned Circuits," Radio Eng., July, 1937.

I. Bady, "Measurement of Q of High Capacity Condensers by the Series-Parallel Method," Signal Corps Report, March, 1943.

E. L. Hall, "VHF Behavior of Radio Components," Electronics, March, 1944.

L. E. Pepperberg, "Determining Q of Capacitors," Electronics, p. 146, Sept., 1945.

R. S. Naslund, "Optimum Q and Impedance of RF Inductors," QST, July, 1941.

"Nomograph for Q Meter," Electr. Ind., p 90, Sept., 1945.

W. J. Spaven, "High Q Measurement," Electronics, p. 166, Nov., 1952.

INDUCTANCE AND IRON CORES

E. Measing, "Coil Testing Methods for Use in Radio Plants," Electronics, p. 248, August, 1935.

D. Pollack, "The Design of Inductance for Frequencies Between 4 and 25 mc," Electrical Eng., Sept., 1937.

D. E. Foster and A. E. Newlon, "Measurement of Iron Cores at Radio Frequencies," Proc. I.R.E., p. 266, May, 1941.

W. J. Polydoroff and A. J. Klapperich, "Effective Permeability of High Frequency Iron Cores," Radio, p. 38, Nov., 1945.

A. I. Forbes Simpson, "The Design of Small Single Layer Coils," Electrical Eng., p. 353, Nov., 1947.

"Basic Theory for Ohmite *Frequency Rated* RF Chokes," Ohmite News, Feb., 1948.

R. E. Lafferty, "Extended Q Meter Measurements," Electronics, Nov., 1951.

E. Both, "Magnetic Powdered Cores for Military Communication," Tele-Tech, p. 36, August, 1952.

National Bureau of Standards Technical Bulletin, "Calibration of Magnetic Materials," Tele-Tech, Jan., 1953.

W. J. Polydoroff, "Powdered Magnetic Cores," Tele-Tech, p. 69, Feb., 1953.

W. T. Cocking, "Q and Inductance," Wireless World, Nov. and Dec., 1949.

H. A. Wheeler, "Inductance Chart for Solenoid Coil," Proc. I.R.E., p. 1398, Dec., 1950.

General Analine and Film Corp. Brochure, "Bibliography on Iron Cores."

Peter H. Haas, "A Radio-Frequency Permeameter," Journal of Research of the National Bureau of Standards, p. 221, Vol. 51, No. 5, November, 1953.

CAPACITANCE AND DIELECTRIC MEASUREMENTS

H. A. Snow, "Losses in Mica and Simple Test Procedure," Radio Eng., Feb., 1937.

A. W. Barber, "Simplified Dielectric Loss Measurements," Radio Eng., July, 1937.

J. R. Townsend, "Testing, Grading, Classifying, and Quality Control of Mica," BTL, August, 1943.

D. M. Hill, "Q Meter for Power Factor and Dielectric Constant," Electr. World, Oct., 1943.

JAN-C-5 Specification: "Capacitors, Mica-Dielectric, Fixed," Nov., 1944.

I. Bady, "Notes on Increasing the Accuracy and Usefulness of the Boonton Q Meter, Model 160-A," Signal Corps Report, Sept., 1945.

T. Hazen, "Dielectric Properties vs. Temperature of Thermosetting Molding Preforms at Radio Frequencies," Electrochem. Soc., Vol. 9, p. 1443, 1946.

K. G. Coutlee, "Judging Mica Quality Electrically," Trans. A.I.E.E., Vol. 64, pp. 735-740.

G. N. Howatt, "Dielectric Properties of Steatite Porcelain," Jour. Am. Ceramic Soc., May, 1946.

A. P. Wangsgard and T. Hazen, "The Q Meter for Dielectric Measurement on Polyethylene and Other Plastics at Frequencies up to 50 mc," Electrochem. Soc., Vol. 90, pp. 361-375, Oct., 1946.

Amer. Soc. for Testing Materials, D-150: "Power Factor and Dielectric Constant of Electrical Insulating Materials."

A. H. Scott and H. L. Curtis, "Edge Correction in the Determination of Dielectric Constant," Jour. of Research, Nat. Bureau of Standards, Vol. 22, pp. 747-775, June, 1939.

J. F. Price, "Effectiveness of By-Pass Capacitors at VHF," Comm. Feb., 1948.

E. W. Greenfield, "Refresher for Dielectric Calculations," Electrical Eng., Oct., 1943.

RESISTANCE

I. Bady, "Notes on Increasing the Accuracy and Usefulness of the Boonton Q Meter, Model 160-A," Signal Corps Report, Sept., 1945.

R. E. Lafferty, "Extended Q Meter Measurements," Electronics, Nov., 1951.

R. Miedke, "Q Meter Impedance Charts," Electronics, p. 112, Jan., 1950.

H. A. Wheeler, "Formulas for Skin Effect," Proc. I.R.E., Sept., 1942.

R. G. Medhurst, "HF Resistance and Self-Capacitance of Single-Layer Solenoids," Wireless Eng., Feb. and Mar., 1947.

TRANSFORMERS

L. E. Pepperberg, "Coupling Coefficient Chart," Electronics, July, 1945.

"Q Meter Method of Determining Actual Coupling to Critical Coupling in IF Transformer," JWL of TWA, Radio Engrg. Rpt. No. RER14, Aug. 45.

S. G. Feldman and M. Goldstein, "Measuring Coupling Coefficients in Tuned RF Transformers," Electronics, Dec., 1950.

R. E. Lafferty, "RF Coupling Nomograph," Electronics, p. 166, Oct., 1952.

P. M. Honnell, "Note on Measuring Coupling Coefficient," Radio, p. 41, Feb., 1945.

C. B. Aiken, "Two-Mesh Coupled Circuit Filters," Proc. I.R.E., Feb., 1937.

"Inductive Coupling of RF Coils," BRC Report, April, 1953.

TRANSMISSION LINES

Ballantine Laboratories, "Measurement of High Frequency Lines," Electronics, April, 1938.

C. Stewart, Jr., "The S Function Method of Measuring Attenuation of Coaxial Radio Frequency Cable," Technical Paper A.I.E.E. 45-134, Oct., 1944.

C. Stewart, Jr., "A Method of Measuring Attenuation of Short Lengths of Coaxial Cable," Proc. I.R.E., p. 946, Jan., 1945.

C. C. Fleming, "Measuring Coaxials at Ultra High Frequencies," BTL, Bell Labs Record, Jan., 1946.

ANTENNAS

G. L. Haller, "Constants of Fixed Antennas on Aircraft," Proc. I.R.E., April, 1938.

G. L. Haller, "Aircraft Antennas," Proc. I.R.E., p. 357, August, 1942.

E. F. Kiernan, "Transport Aircraft Antenna Characteristics," Electronics, Dec., 1944.

W. S. Bachman, "Loop Antenna Coupling Transformer Design," Proc. I.R.E., p. 865, Dec., 1945.

J. E. Browder and V. J. Young, "Design Values for Loop-Antenna Input Circuits," Proc. I.R.E., May, 1947.

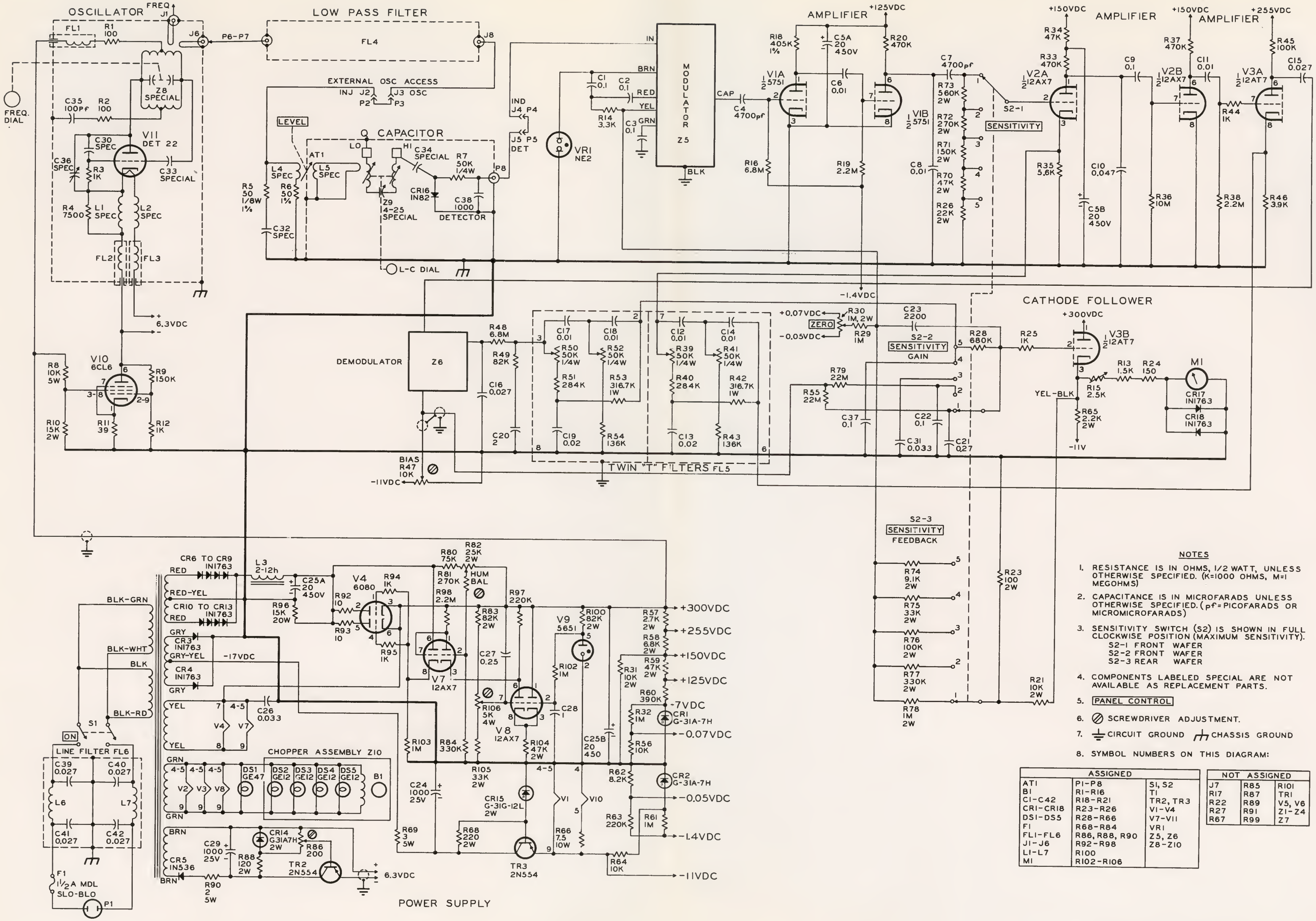
E. M. Kendell, "Receiver Loop - Antenna Design Factors," Comm. Nov., 1945.

SPECIAL MEASUREMENTS

B. N. Prakash, "On the Measurement of Negative Impedances with a Q Meter," Electrotechniques, pp. 69-73, Dec., 1946.

H. A. Bierwirth and C. N. Hoyler, "Radio Frequency Heating Applied to Wood Gluing," Proc. I.R.E., Oct., 1943.

W. D. George, M. C. Selby, and R. Scolink, "Precision Measurement of Electrical Characteristics of Quartz Crystal Units," Proc. I.R.E., p. 1122, Sept., 1948.



NOTES

1. RESISTANCE IS IN OHMS, 1/2 WATT, UNLESS OTHERWISE SPECIFIED. (K=1000 OHMS, M=1 MEGOHMS)
2. CAPACITANCE IS IN MICROFARADS UNLESS OTHERWISE SPECIFIED. (pf=PICOFARADS OR MICROMICROFARADS)
3. SENSITIVITY SWITCH (S2) IS SHOWN IN FULL CLOCKWISE POSITION (MAXIMUM SENSITIVITY).
S2-1 FRONT WAFER
S2-2 FRONT WAFER
S2-3 REAR WAFER
4. COMPONENTS LABELED SPECIAL ARE NOT AVAILABLE AS REPLACEMENT PARTS.
5. PANEL CONTROL
6. SCREWDRIVER ADJUSTMENT.
7. CIRCUIT GROUND CHASSIS GROUND
8. SYMBOL NUMBERS ON THIS DIAGRAM:

ASSIGNED		
AT1	P1-P8	S1, S2
B1	R1-R16	T1
C1-C42	R18-R21	TR2, TR3
CR1-CR18	R23-R26	V1-V4
DS1-DS5	R28-R66	V7-V11
F1	R68-R84	VR1
FL1-FL6	R86, R88, R90	Z5, Z6
J1-J6	R92-R98	Z8-Z10
L1-L7	R100	
M1	R102-R106	

NOT ASSIGNED		
J7	R85	R101
R17	R87	TR1
R22	R89	V5, V6
R27	R91	Z1-Z4
R67	R99	Z7

Figure 26. Type 280-A Schematic diagram